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Etzkorn

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(45) **Date of Patent: Feb. 24, 2015**

(54) **ASSEMBLING THIN SILICON CHIPS ON A CONTACT LENS**

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(51) **Int. Cl.**

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H01L 23/48	(2006.01)
H01L 21/56	(2006.01)
G02C 7/04	(2006.01)
H01L 23/00	(2006.01)

(52) **U.S. Cl.**

CPC ***H01L 23/48*** (2013.01); ***H01L 21/563*** (2013.01); ***G02C 7/049*** (2013.01); ***H01L 24/97*** (2013.01); *H01L 2924/10253* (2013.01)

USPC **351/159.03**; 351/159.39

(58) **Field of Classification Search**

CPC H01L 2924/00; H01L 2224/48227; H01L 27/14618; H01L 33/08; H01L 27/14627

USPC .... 351/159, 160 R

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,958,560 A 5/1976 March
4,014,321 A 3/1977 March
4,055,378 A 10/1977 Feneberg et al.
4,122,942 A 10/1978 Wolfson
4,136,250 A 1/1979 Mueller et al.
4,143,949 A 3/1979 Chen
4,153,641 A 5/1979 Deichert et al.
4,214,014 A 7/1980 Hofer et al.
4,309,085 A 1/1982 Morrison

(Continued)

FOREIGN PATENT DOCUMENTS

EP 0369942 5/1990
EP 686372 12/1995

(Continued)

OTHER PUBLICATIONS

Badugu et al., “A Glucose Sensing Contact Lens: A Non-Invasive Technique for Continuous Physiological Glucose Monitoring,” Journal of Fluorescence, Sep. 2003, pp. 371-374, vol. 13, No. 5.

(Continued)

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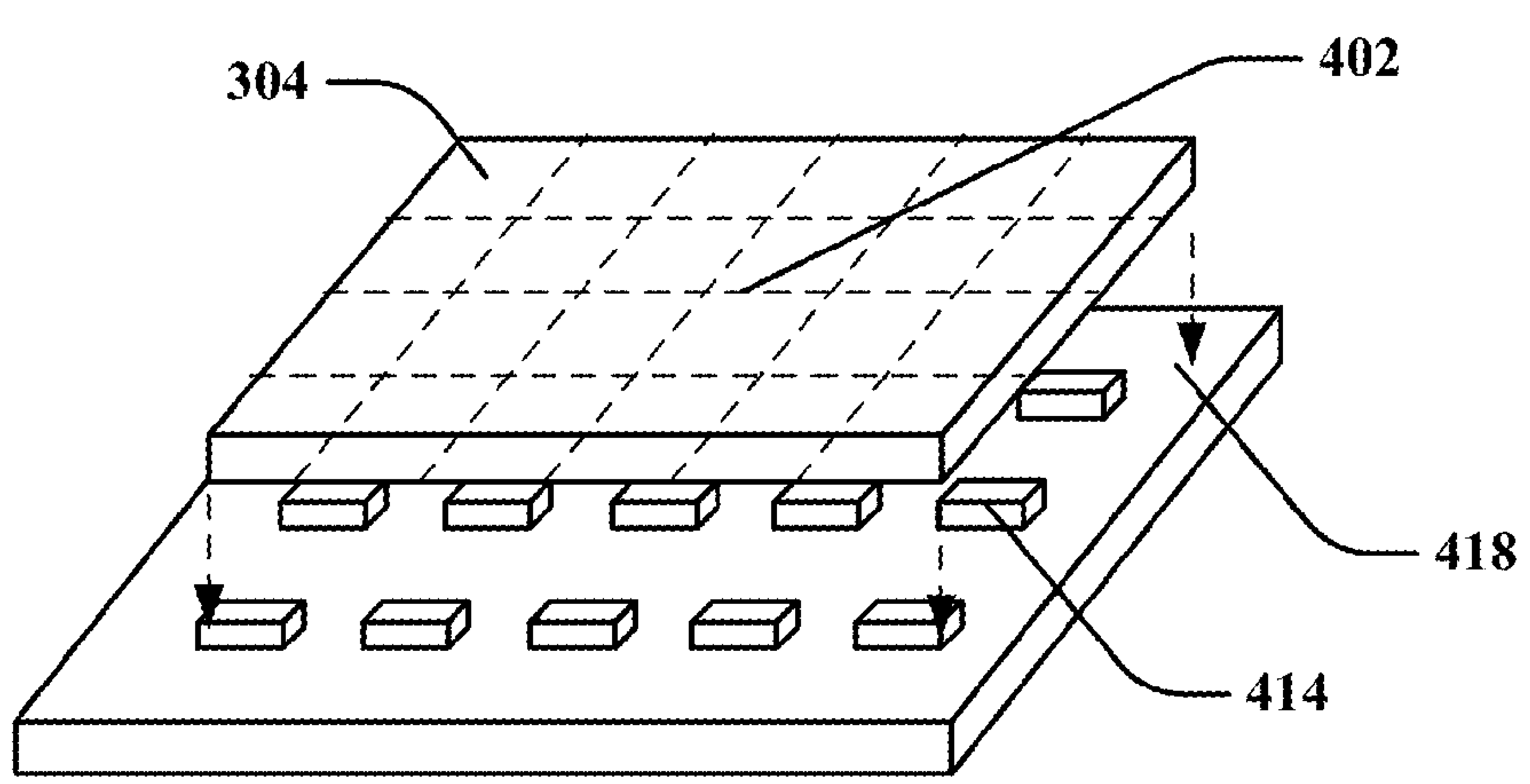
(57) **ABSTRACT**

A contact lens having a thin silicon chip integrated therein is provided along with methods for assembling the silicon chip within the contact lens. In an aspect, a method includes creating a plurality of lens contact pads on a lens substrate and creating a plurality of chip contact pads on a chip. The method further involves applying assembly bonding material to the each of the plurality of lens contact pads or chip contact pads, aligning the plurality of lens contact pads with the plurality of chip contact pads, bonding the chip to the lens substrate via the assembly bonding material using flip chip bonding, and forming a contact lens with the lens substrate.

21 Claims, 15 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

4,312,575 A 1/1982 Peyman et al.
4,401,371 A 8/1983 Neefe
4,463,149 A 7/1984 Ellis
4,555,372 A 11/1985 Kunzler et al.
4,604,479 A 8/1986 Ellis
4,632,844 A 12/1986 Yanagihara et al.
4,686,267 A 8/1987 Ellis et al.
4,740,533 A 4/1988 Su et al.
4,826,936 A 5/1989 Ellis
4,996,275 A 2/1991 Ellis et al.
4,997,770 A 3/1991 Giles et al.
5,032,658 A 7/1991 Baron et al.
5,034,461 A 7/1991 Lai et al.
5,070,215 A 12/1991 Bambury et al.
5,135,297 A 8/1992 Valint
5,177,165 A 1/1993 Valint et al.
5,177,168 A 1/1993 Baron
5,219,965 A 6/1993 Valint et al.
5,260,000 A 11/1993 Nandu et al.
5,271,875 A 12/1993 Appleton et al.
5,310,779 A 5/1994 Lai
5,321,108 A 6/1994 Kunzler et al.
5,326,584 A 7/1994 Kamel et al.
5,336,797 A 8/1994 McGee et al.
5,346,976 A 9/1994 Ellis et al.
5,358,995 A 10/1994 Lai et al.
5,364,918 A 11/1994 Valint et al.
5,387,662 A 2/1995 Kunzler et al.
5,449,729 A 9/1995 Lai
5,472,436 A 12/1995 Fremstad
5,512,205 A 4/1996 Lai
5,585,871 A 12/1996 Linden
5,610,252 A 3/1997 Bambury et al.
5,616,757 A 4/1997 Bambury et al.
5,682,210 A 10/1997 Weirich
5,708,094 A 1/1998 Lai et al.
5,710,302 A 1/1998 Kunzler et al.
5,714,557 A 2/1998 Kunzler et al.
5,726,733 A 3/1998 Lai et al.
5,760,100 A 6/1998 Nicolson et al.
5,908,906 A 6/1999 Kunzler et al.
5,981,669 A 11/1999 Valint et al.
6,087,941 A 7/2000 Ferraz
6,131,580 A 10/2000 Ratner et al.
6,134,736 A 10/2000 Pankow
6,193,369 B1 2/2001 Valint et al.
6,200,626 B1 3/2001 Grobe et al.
6,213,604 B1 4/2001 Valint et al.
6,312,393 B1 11/2001 Abreu
6,348,507 B1 2/2002 Heiler et al.
6,366,794 B1 4/2002 Moussy et al.
6,423,001 B1 7/2002 Abreu
6,428,839 B1 8/2002 Kunzler et al.
6,431,705 B1 8/2002 Linden
6,440,571 B1 8/2002 Valint et al.
6,450,642 B1 9/2002 Jethmalani et al.
6,532,298 B1 3/2003 Cambier et al.
6,550,915 B1 4/2003 Grobe
6,570,386 B2 5/2003 Goldstein
6,579,235 B1 6/2003 Abita et al.
6,599,559 B1 7/2003 McGee et al.
6,614,408 B1 9/2003 Mann
6,630,243 B2 10/2003 Valint et al.
6,638,563 B2 10/2003 McGee et al.
6,726,322 B2 4/2004 Andino et al.
6,735,328 B1 5/2004 Helbing et al.
6,779,888 B2 8/2004 Marmo
6,804,560 B2 10/2004 Nisch et al.
6,851,805 B2 2/2005 Blum et al.
6,885,818 B2 4/2005 Goldstein
6,939,299 B1 9/2005 Petersen et al.
6,980,842 B2 12/2005 March et al.
7,018,040 B2 3/2006 Blum et al.
7,131,945 B2 11/2006 Fink et al.
7,169,106 B2 1/2007 Fleischman et al.
7,398,119 B2 7/2008 Lambert et al.
7,423,801 B2 9/2008 Kaufman et al.
7,429,465 B2 9/2008 Muller et al.
7,441,892 B2 10/2008 Hsu
7,443,016 B2 10/2008 Tsai et al.
7,450,981 B2 11/2008 Jeon
7,639,845 B2 12/2009 Utsunomiya
7,654,671 B2 2/2010 Glynn
7,699,465 B2 4/2010 Dootjes et al.
7,728,949 B2 6/2010 Clarke et al.
7,751,896 B2 7/2010 Graf et al.
7,799,243 B2 9/2010 Mather et al.
7,809,417 B2 10/2010 Abreu
7,878,650 B2 2/2011 Fritsch et al.
7,885,698 B2 2/2011 Feldman
7,907,931 B2 3/2011 Hartigan et al.
7,926,940 B2 4/2011 Blum et al.
7,931,832 B2 4/2011 Pugh et al.
7,964,390 B2 6/2011 Rozakis et al.
8,080,187 B2 12/2011 Tepedino, Jr. et al.
8,096,654 B2 1/2012 Amirparviz et al.
8,118,752 B2 2/2012 Hetling et al.
8,142,016 B2 3/2012 Legerton et al.
8,224,415 B2 7/2012 Budiman
2002/0193674 A1 12/2002 Fleischman et al.
2003/0179094 A1 9/2003 Abreu
2004/0027536 A1 2/2004 Blum et al.
2004/0116794 A1 6/2004 Fink et al.
2005/0045589 A1 3/2005 Rastogi et al.
2005/0221276 A1 10/2005 Rozakis et al.
2006/0254369 A1* 11/2006 Yoon et al. 73/862.041
2007/0016074 A1 1/2007 Abreu
2007/0030443 A1 2/2007 Chapoy et al.
2007/0121065 A1 5/2007 Cox et al.
2007/0188710 A1 8/2007 Hetling et al.
2008/0208335 A1 8/2008 Blum et al.
2008/0218696 A1 9/2008 Mir
2009/0033863 A1 2/2009 Blum et al.
2009/0036761 A1 2/2009 Abreu
2009/0057164 A1 3/2009 Minick et al.
2009/0076367 A1 3/2009 Sit et al.
2009/0118604 A1 5/2009 Phan et al.
2009/0189830 A1 7/2009 Deering et al.
2009/0196460 A1 8/2009 Jakobs et al.
2010/0001926 A1 1/2010 Amirparviz et al.
2010/0013114 A1 1/2010 Bowers et al.
2010/0016704 A1 1/2010 Naber et al.
2010/0028559 A1 2/2010 Yan et al.
2010/0072643 A1 3/2010 Pugh et al.
2010/0103368 A1* 4/2010 Amirparviz et al. 351/158
2010/0109175 A1 5/2010 Pugh et al.
2010/0110372 A1 5/2010 Pugh et al.
2010/0113901 A1 5/2010 Zhang et al.
2010/0133510 A1 6/2010 Kim et al.
2010/0249548 A1 9/2010 Muller
2011/0015512 A1 1/2011 Pan et al.
2011/0028807 A1 2/2011 Abreu
2011/0040161 A1 2/2011 Abreu
2011/0055317 A1 3/2011 Vonog et al.
2011/0084834 A1 4/2011 Sabeta
2011/0116035 A1 5/2011 Fritsch et al.
2011/0157541 A1 6/2011 Peyman
2011/0157544 A1 6/2011 Pugh et al.
2011/0184271 A1 7/2011 Veciana et al.
2011/0254158 A1* 10/2011 Kaylani et al. 257/737
2011/0274680 A1 11/2011 Mazed et al.
2011/0286064 A1 11/2011 Burles et al.
2011/0298794 A1 12/2011 Freedman
2012/0026458 A1 2/2012 Qiu et al.
2012/0038881 A1 2/2012 Amirparviz et al.
2012/0041287 A1 2/2012 Goodall et al.
2012/0041552 A1 2/2012 Chuck et al.
2012/0069254 A1 3/2012 Burton
2012/0074598 A1* 3/2012 Kalz 257/788
2012/0075168 A1 3/2012 Osterhout et al.
2012/0075574 A1 3/2012 Pugh et al.
2012/0078071 A1 3/2012 Bohm et al.
2012/0088258 A1 4/2012 Bishop et al.
2012/0092612 A1 4/2012 Binder

(56) **References Cited**

U.S. PATENT DOCUMENTS

2012/0109296	A1	5/2012	Fan	
2012/0177576	A1	7/2012	Hu	
2012/0201755	A1	8/2012	Rozakis et al.	
2012/0206691	A1	8/2012	Iwai	
2012/0245444	A1	9/2012	Otis et al.	
2012/0259188	A1 *	10/2012	Besling	600/319

FOREIGN PATENT DOCUMENTS

EP	1061874	12/2000
EP	1617757	1/2006
EP	1818008	8/2007
EP	1947501	7/2008
EP	2457122	5/2012
JP	2003-195230	7/2003
WO	9504609	2/1995
WO	0116641	3/2001
WO	0134312	5/2001
WO	03065876	8/2003
WO	2004060431	7/2004
WO	2004064629	8/2004
WO	2006015315	2/2006
WO	2009094643	7/2009
WO	2010105728	9/2010
WO	2010133317	11/2010
WO	2011/011344	1/2011
WO	2011034592	3/2011
WO	2011035228	3/2011
WO	2011035262	3/2011
WO	2011083105	7/2011
WO	2011163080	12/2011
WO	2012035429	3/2012
WO	2012037455	3/2012
WO	2012051167	4/2012
WO	2012051223	4/2012
WO	2012052765	4/2012

OTHER PUBLICATIONS

Carlson et al., "A 20 mV Input Boost Converter With Efficient Digital Control for Thermoelectric Energy Harvesting," IEEE Journal of Solid-State Circuits, Apr. 2010, pp. 741-750, vol. 45, No. 4.

Chu et al., "Biomedical soft contact-lens sensor for in situ ocular biomonitoring of tear contents," Biomed Microdevices, 2011, pp. 603-611, vol. 13.

Chu et al., "Soft contact lens biosensor for in situ monitoring of tear glucose as non-invasive blood sugar assessment," Talanta, 2011, pp. 960-965, vol. 83.

Ho et al., "Contact Lens With Integrated Inorganic Semiconductor Devices," MEMS 2008. IEEE 21st International Conference on. IEEE, 2008., pp. 403-406.

Lähdesmäki et al., "Possibilities for Continuous Glucose Monitoring by a Functional Contact Lens," IEEE Instrumentation & Measurement Magazine, Jun. 2010, pp. 14-17.

Lingley et al., "A contact lens with integrated micro solar cells," Microsyst Technol, 2012, pp. 453-458, vol. 18.

Parviz, Babak A., "For Your Eyes Only," IEEE Spectrum, Sep. 2009, pp. 36-41.

Saeedi, E. et al., "Self-assembled crystalline semiconductor optoelectronics on glass and plastic," J. Micromech. Microeng., 2008, pp. 1-7, vol. 18.

Saeedi et al., "Self-Assembled Inorganic Micro-Display on Plastic," Micro Electro Mechanical Systems, 2007. MEMS. IEEE 20th International Conference on. IEEE, 2007., pp. 755-758.

Sensimed Triggerfish, Sensimed Brochure, 2010, 10 pages.

Shih, Yi-Chun et al., "An Inductorless DC-DC Converter for Energy Harvesting With a 1.2-μW Bandgap-Referenced Output Controller," IEEE Transactions on Circuits and Systems-II: Express Briefs, Dec. 2011, pp. 832-836, vol. 58, No. 12.

Shum et al., "Functional modular contact lens," Proc. of SPIE, 2009, pp. 73970K-1 to 73970K-8, vol. 7397.

Stauth et al., "Self-assembled single-crystal silicon circuits on plastic," PNAS, Sep. 19, 2006, pp. 13922-13927, vol. 103, No. 38.

Yao, H. et al., "A contact lens with integrated telecommunication circuit and sensors for wireless and continuous tear glucose monitoring," J. Micromech. Microeng., 2012, pp. 1-10, vol. 22.

Yao, H. et al., "A Dual Microscal Glucose Sensor on a Contact Lens, Tested in Conditions Mimicking the Eye," Micro Electro Mechanical Systems (MEMS), 2011 IEEE 24th International Conference on. IEEE, 2011, pp. 25-28.

Yao et al., "A contact lens with embedded sensor for monitoring tear glucose level," Biosensors and Bioelectronics, 2011, pp. 3290-3296, vol. 26.

Yao, H. et al., "A Soft Hydrogel Contact Lens with an Encapsulated Sensor for Tear Glucose Monitoring," Micro Electro Mechanical Systems (MEMS), 2012 IEEE 25th International Conference on. IEEE, 2012, pp. 769-772.

Yeager et al., "A 9 μA, Addressable Gent Sensor Tag for Biosignal Acquistion," IEEE Journal of Solid-State Circuits, Oct. 2010, pp. 2198-2209, vol. 45, No. 10.

Zhang et al., "Design for Ultra-Low Power Biopotential Amplifiers for Biosignal Acquistion Applications," IEEE Transactions on Biomedical Circuits and Systems, 2012, pp. 344-355, vol. 6, No. 4.

Wall, K., "Active contact lens that lets you see like the Terminator patented," Feb. 10, 2012, http://www.patexia.com/feed/active-contact-lens-that-lets-you-see-like-the-terminator-patented-2407, Last accessed Mar. 28, 2012, 5 pages.

Parviz, Babak A., "Augmented Reality in a Contact Lens," IEEE Spectrum, Sep. 2009, http://spectrum.ieee.org/biomedical/bionics/augmented-reality-in-a-contact-lens/0, Last accessed Mar. 14, 2012, 6 pages.

Bionic contact lens 'to project emails before eyes,' http://www.kurzweilai.net/forums/topic/bionic-contact-lens-to-project-emails-before-eyes, Last accessed Mar. 14, 2012, 2 pages.

Tweedie, et al., "Contact creep compliance of viscoelastic materials via nanoindentation," J. Mater. Res., Jun. 2006, vol. 21, No. 2, pp. 1576-1589, Materials Research Society.

Brahim, et al., "Polypyrrole-hydrogel composites for the construction of clinically important biosensors," 2002, Biosensors & Bioelectronics, vol. 17, pp. 53-59.

Huang, et al., "Wrinkling of Ultrathin Polymer Films," Mater. Res. Soc. Symp. Proc., 2006, vol. 924, 6 pages, Materials Research Society.

Zarbin, et al., "Nanotechnology in ophthalmology," Can J Ophthalmol, 2010, vol. 45, No. 5, pp. 457-476.

Selner, et al., "Novel Contact Lens Electrode Array for Multi-electrode Electroretinography (meERG)," IEEE, 2011, 2 pages.

Liao, et al., "A 3-μW CMOS Glucose Sensor for Wireless Contact-Lens Tear Glucose Monitoring," IEEE Journal of Solid-State Circuits, Jan. 2012, vol. 47, No. 1, pp. 335-344.

Chen, et al., "Microfabricated Implantable Parylene-Based Wireless Passive Intraocular Pressure Sensors," Journal of Microelectromechanical Systems, Dec. 2008, vol. 17, No. 6, pp. 1342-1351.

Thomas, et al., "Functional Contact Lenses for Remote Health Monitoring in Developing Countries," IEEE Global Humanitarian Technology Conference, 2011, pp. 212-217, IEEE Computer Society.

Pandey, et al., "A Fully Integrated RF-Powered Contact Lens With a Single Element Display," IEEE Transactions on Biomedical Circuits and Systems, Dec. 2010, vol. 4, No. 6, pages.

Lingley, et al., "Multipurpose integrated active contact lenses," SPIE, 2009, 2 pages.

Chu, et al., "Soft Contact-lens Sensor for Monitoring Tear Sugar as Novel Wearable Device of Body Sensor Network," http://www.ksi.edu/seke/dms11/DMS/2_Kohji_Mitsubayashi.pdf, Last accessed Jul. 27, 2012, 4 pages.

Liao, et al., "A 3μW Wirelessly Powered CMOS Glucose Sensor for an Active Contact Lens," 2011 IEEE International Solid-State Circuits Conference, Session 2, Feb. 21, 2011, 3 pages.

Hurst, "How contact lenses could help save your life," Mail Online, Apr. 19, 2010, http://www.dailymail.co.uk/health/article-1267345/How-contact-lenses-help-save-life.html, Last accessed Jul. 27, 2012.

(56) **References Cited**

OTHER PUBLICATIONS

Lončar, et al., "Design and Fabrication of Silicon Photonic Crystal Optical Waveguides," Journal of Lightwave Technology, Oct. 2000, vol. 18, No. 10, pp. 1402-1411.
Liu, et al., "Miniature Amperometric Self-Powered Continuous Glucose Sensor with Linear Response," Analytical Chemistry, 7 pages.
Baxter, "Capacitive Sensors," 2000, 17 pages.
Lingley, et al., "A Single-Pixel Wireless Contact Lens Display," Journal of Micromechanics and Microengineering, 2011, 9 pages.
"Polyvinylidene fluoride," Wikipedia, http://en.wikipedia.org/wiki/Polyvinylidene_fluoride, Last accessed Mar. 30, 2012, 4 pages.
Murdan, "Electro-responsive drug delivery from hydrogels," Journal of Controlled Release, 2003, vol. 92, pp. 1-17.
Haders, "New Controlled Release Technologies Broaden Opportunities for Ophthalmic Therapies," Drug Delivery Technology, Jul./Aug. 2009, vol. 8, No. 7, pp. 48-53.
Singh, et al., "Novel Approaches in Formulation and Drug Delivery using Contact Lenses," Journal of Basic and Clinical Pharmacy, May 2011, vol. 2, Issue 2, pp. 87-101.
"Contact Lenses: Look Into My Eyes," The Economist, Jun. 2, 2011, http://www.economist.com/node/18750624/print, Last accessed Mar. 13, 2012, 8 pages.
Holloway, "Microsoft developing electronic contact lens to monitor blood sugar," Gizmag, Jan. 5, 2012, http://www.gizmag.com/microsoft-electronic-diabetic-contact-lens/20987/, Last accessed Mar. 13, 2012, 5 pages.
Unpublished U.S. Appl. No. 13/240,994, Titled "See-Through Display With Infrared Eye-Tracker," filed Sep. 22, 2011, 38 pages.
Unpublished U.S. Appl. No. 13/209,706, Titled "Optical Display System and Method with Gaze Tracking," filed Aug. 15, 2011, 30 pages.
Adler, "What types of statistical analysis do scientists use most often?" O'Reilly Community, Jan. 15, 2010, 2 pages, http://broadcast.oreilly.com/2010/01/what-types-of-statistical-anal.html, Last accessed Sep. 4, 2012.
Bull, "Different Types of Statistical Analysis," Article Click, Feb. 4, 2008, 4 pages, http://www.articleclick.com/Article/Different-Types-Of-Statistical-Analysis/968252, Last accessed Sep. 4, 2012.
"Understanding pH measurement," Sensorland, 8 pages, http://www.sensorland.com/HowPage037.html, Last accessed Sep. 6, 2012.
"Regression analysis," Wikipedia, 11 pages, http://en.wikipedia.org/wiki/Regression_analysis, Last accessed Sep. 6, 2012.
"Statistics," Wikipedia, 10 pages, http://en.wikipedia.org/wiki/Statistics, Last accessed Sep. 6, 2012.
"Nonlinear regression," Wikipedia, 4 pages, http://en.wikipedia.org/wiki/Nonlinear_regression, Last accessed Sep. 10, 2012.
"Linear regression," Wikipedia, 15 pages, http://en.wikipedia.org/wiki/Linear_regression, Last accessed Sep. 10, 2012.
"Integrated circuit," Wikipedia, 9 pages, http://en.wikipedia.org/wiki/Integrated_circuit, Last accessed Sep. 10, 2012.
"Photolithography," Wikipedia, 8 pages, http://en.wikipedia.org/wiki/Photolithography, Last accessed Sep. 10, 2012.
"Alcohol Detection Technologies: Present and Future," American Beverage Institute, 9 pages.
Harding, et al., "Alcohol Toxicology for Prosecutors: Targeting Hardcore Impaired Drivers," American Prosecutors Research Institute, Jul. 2003, 40 pages.
Kim, et al., "Oral Alcohol Administration Disturbs Tear Film and Ocular Surface," American Academy of Ophthalmology, 2012, 7 pages.
Quick, "Color-changing electrochromic lens technology has fashion and military applications," Gizmag, Jul. 12, 2011, http://www.gizmag.com/electrochromic-lens-technology/19191/, Last accessed Apr. 12, 2012, 4 pages.
Chu, "Contact Lenses that Respond to Light," Technology Review, Nov. 10, 2009, http://www.technologyreview.com/printer_friendly_article.aspx?id=23922, Last accessed Apr. 12, 2012, 2 pages.
International Searching Authority, International Search Report and Written Opinion for PCT/US2013/059256 mailed Dec. 10, 2013, 10 pages.

* cited by examiner

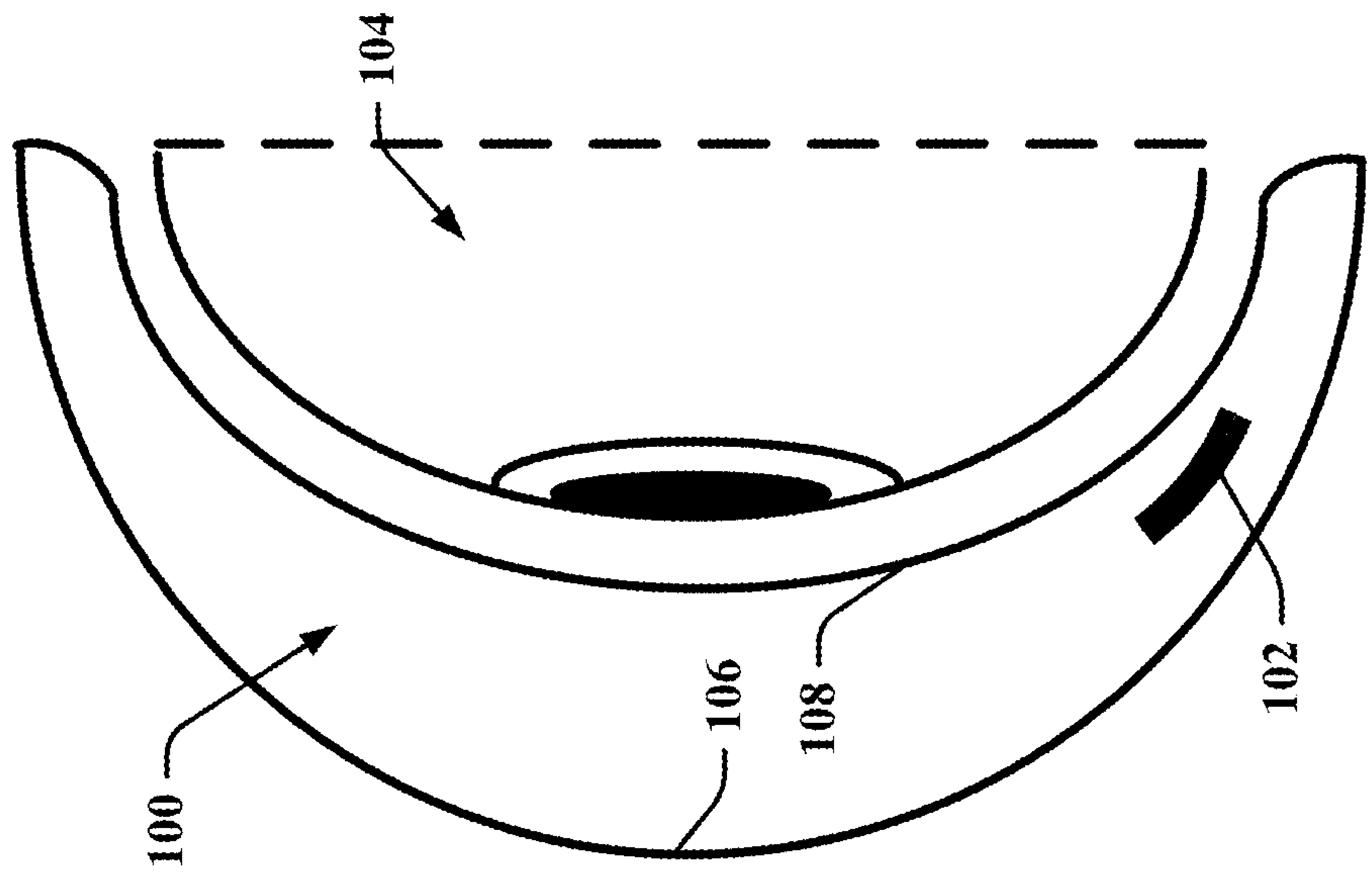


FIG. 1B

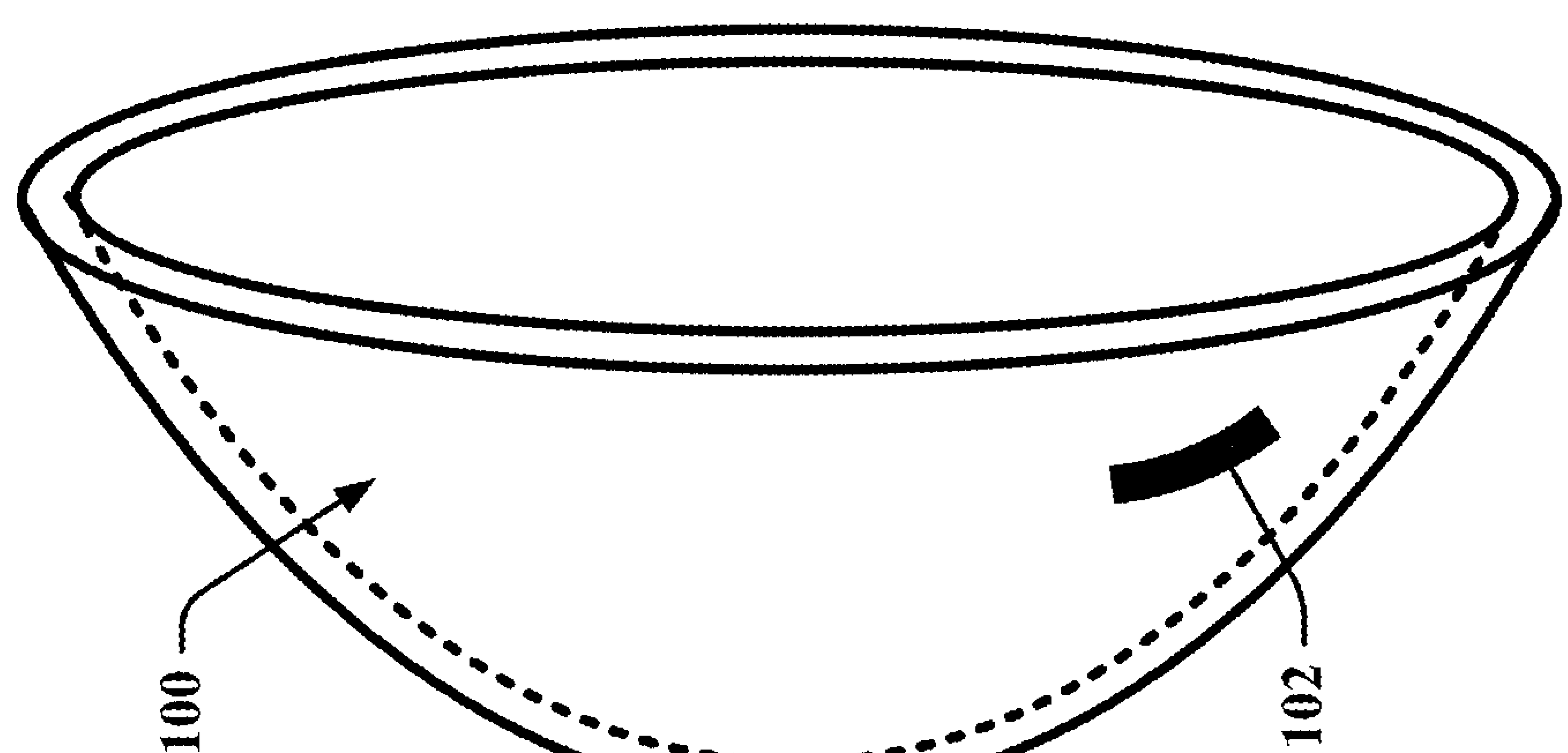


FIG. 1A

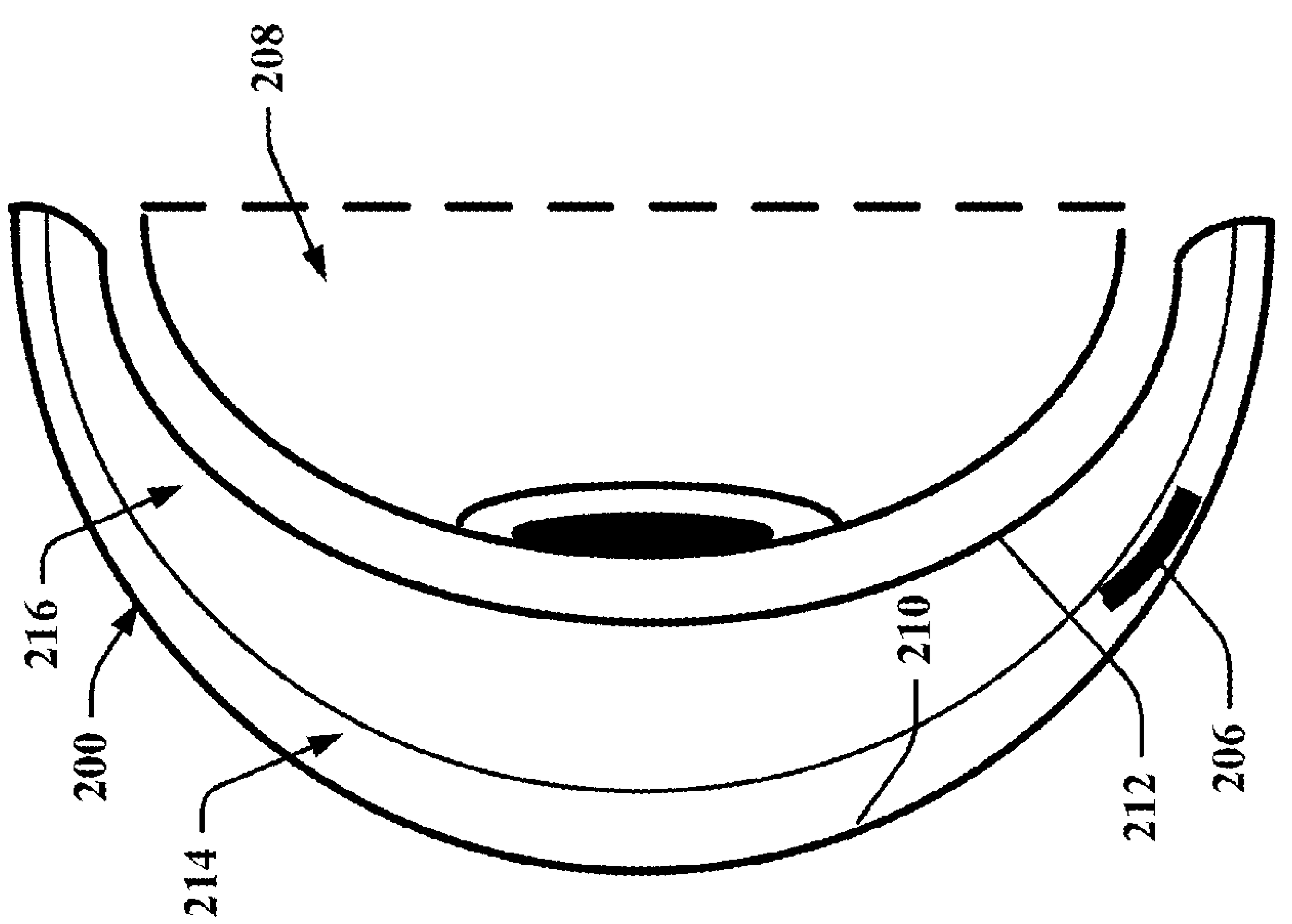


FIG. 2A

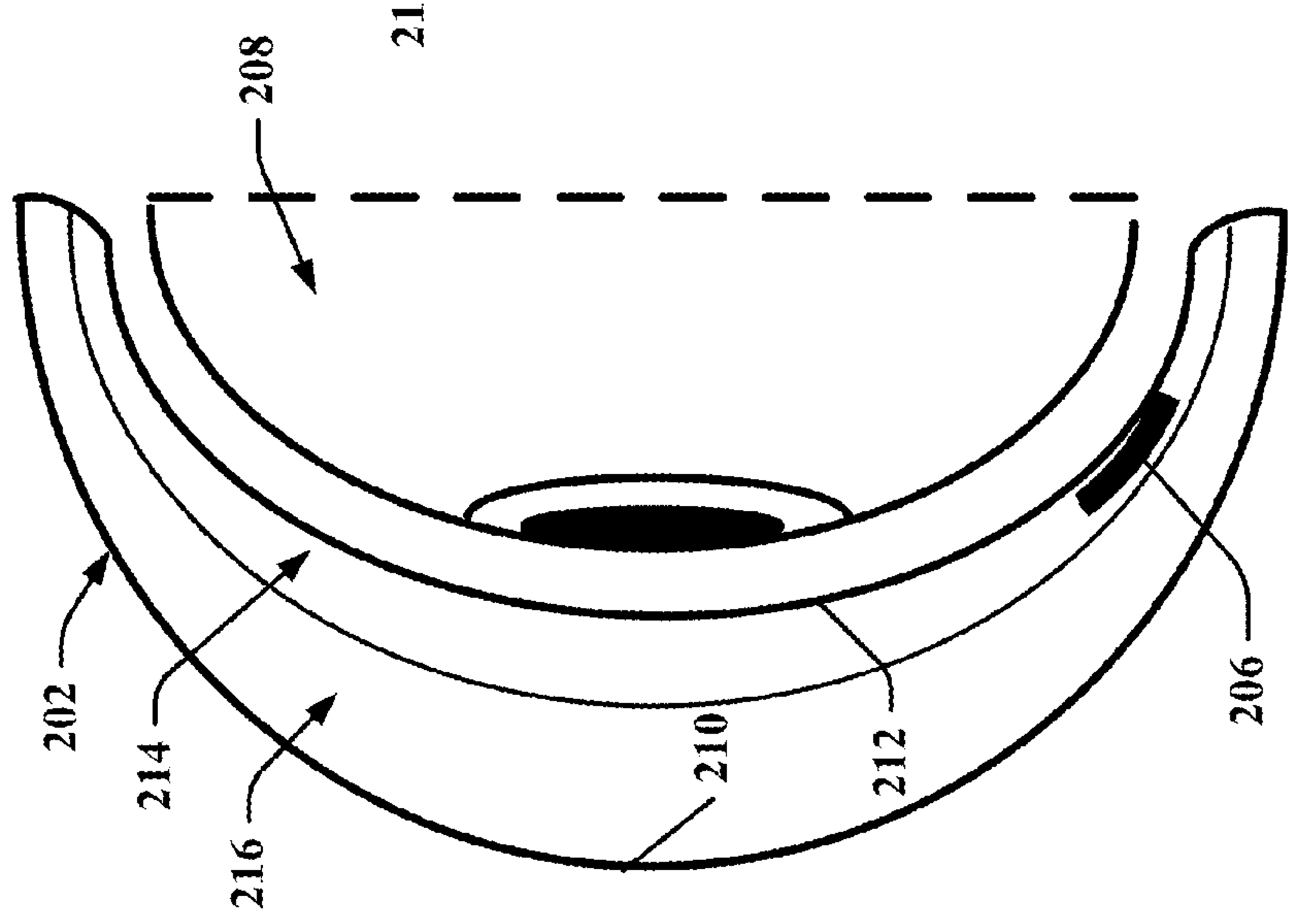


FIG. 2B

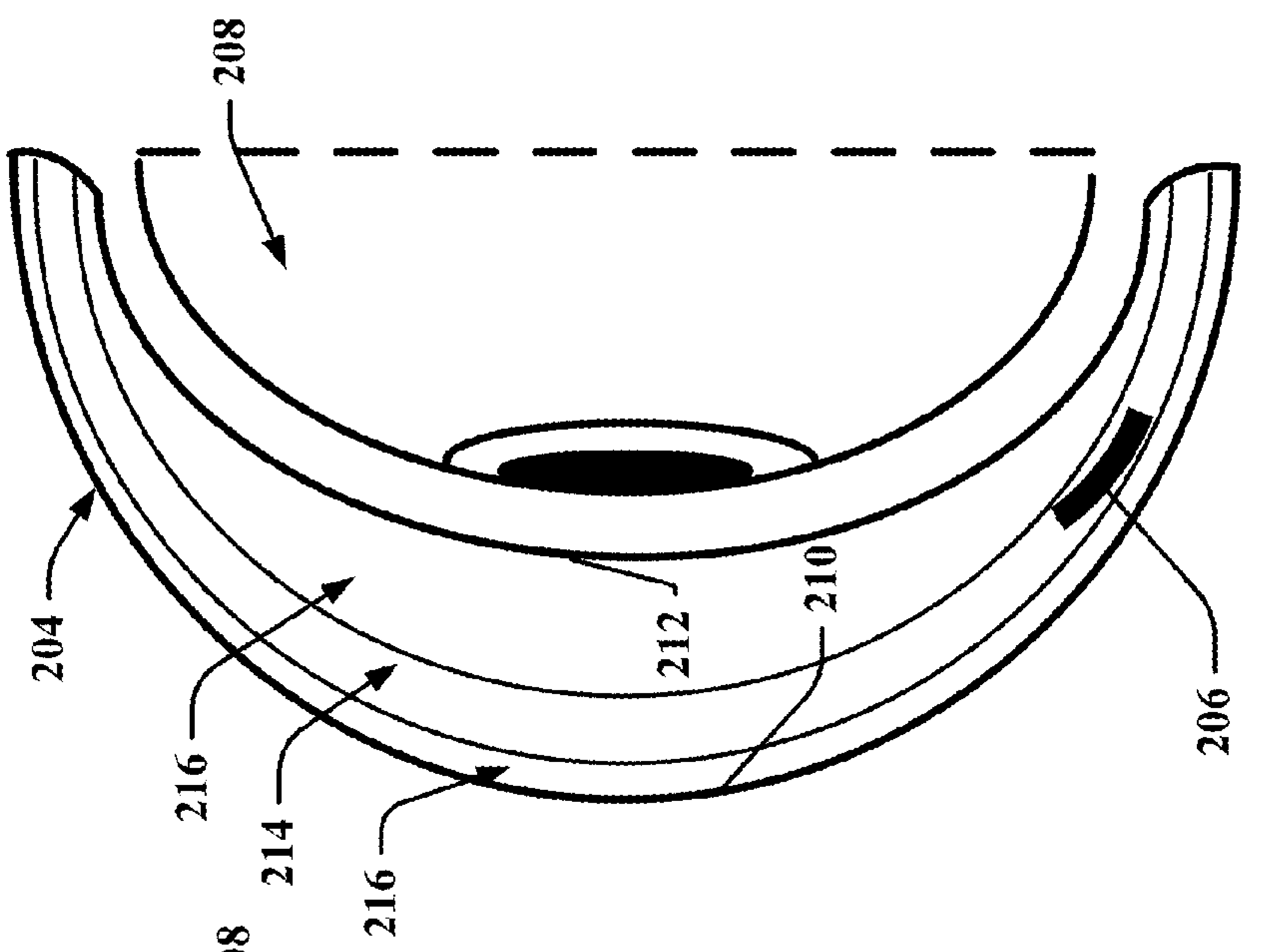


FIG. 2C

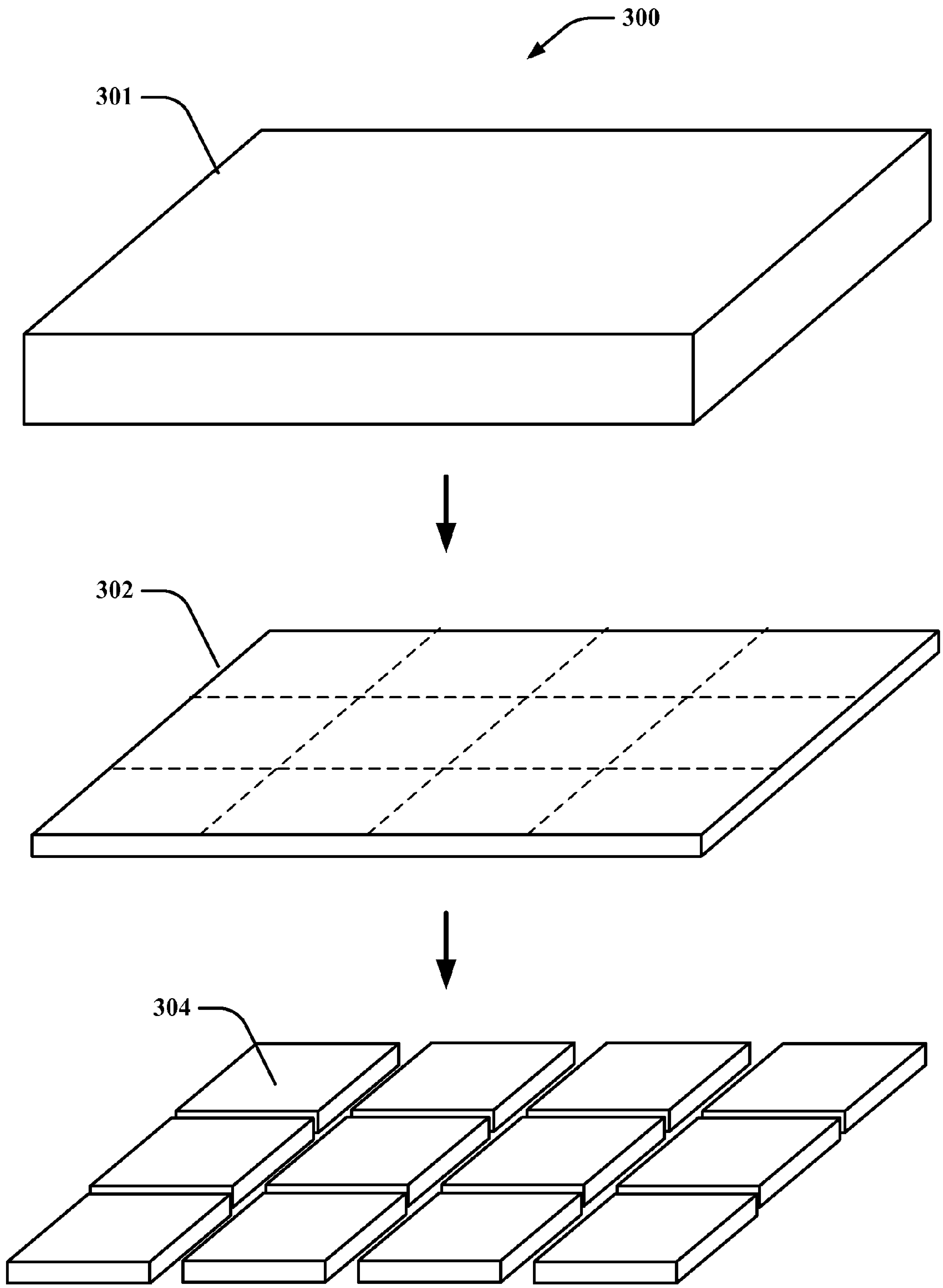


FIG. 3

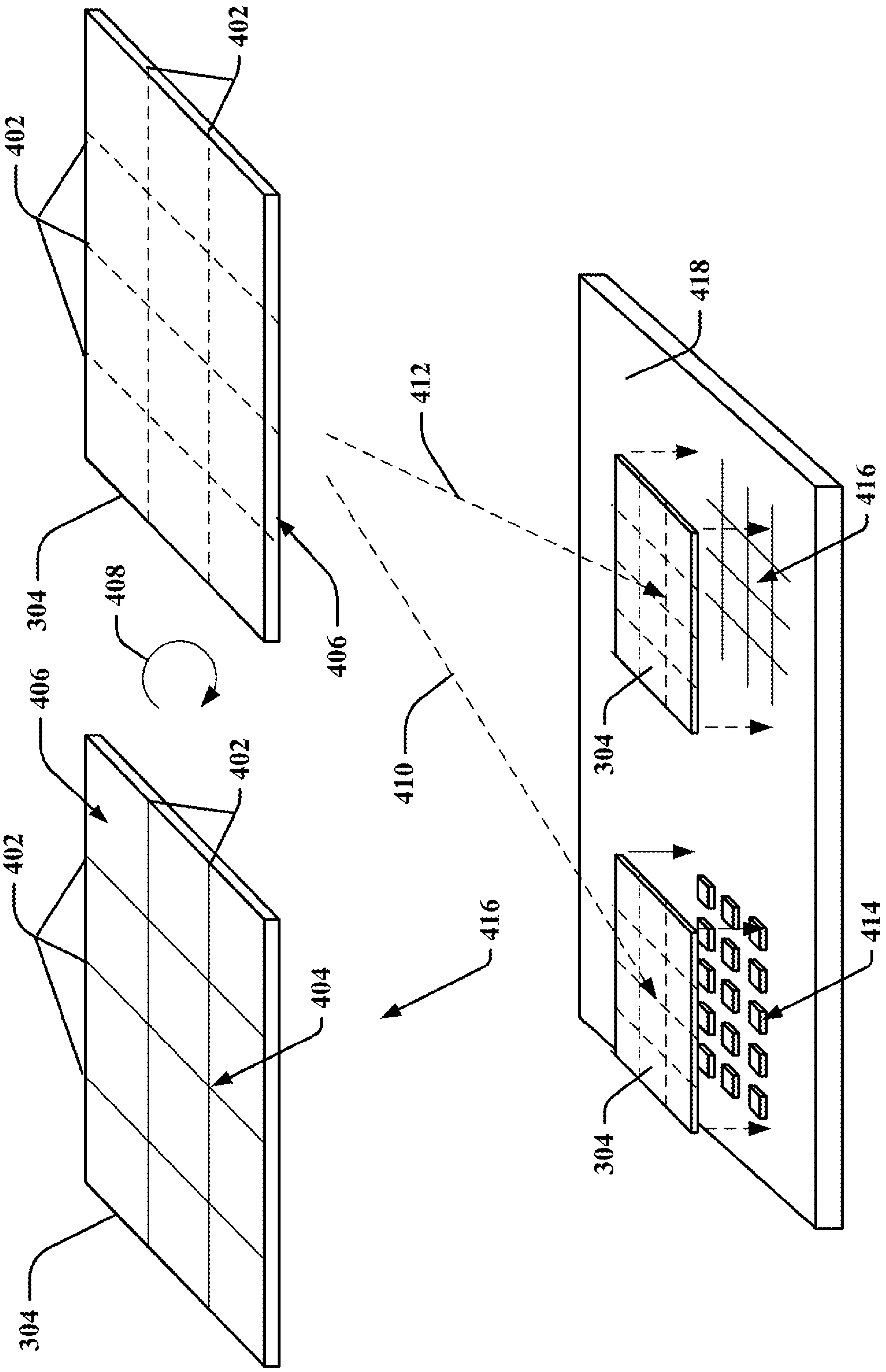


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FIG. 4

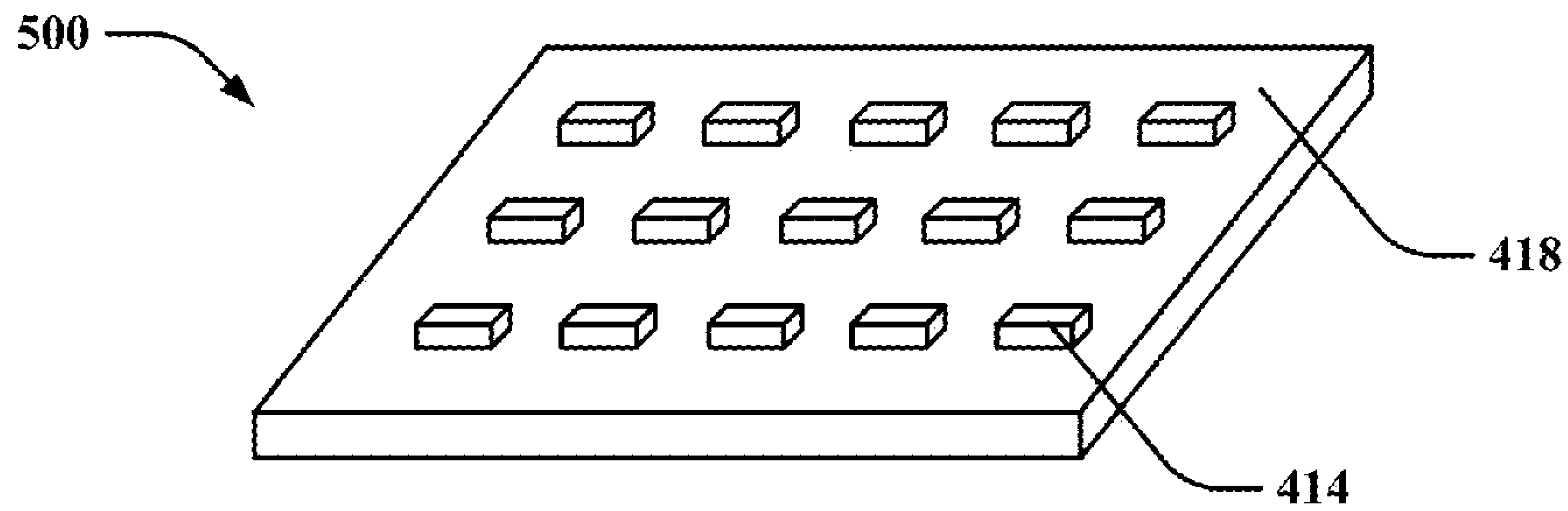

FIG. 5A

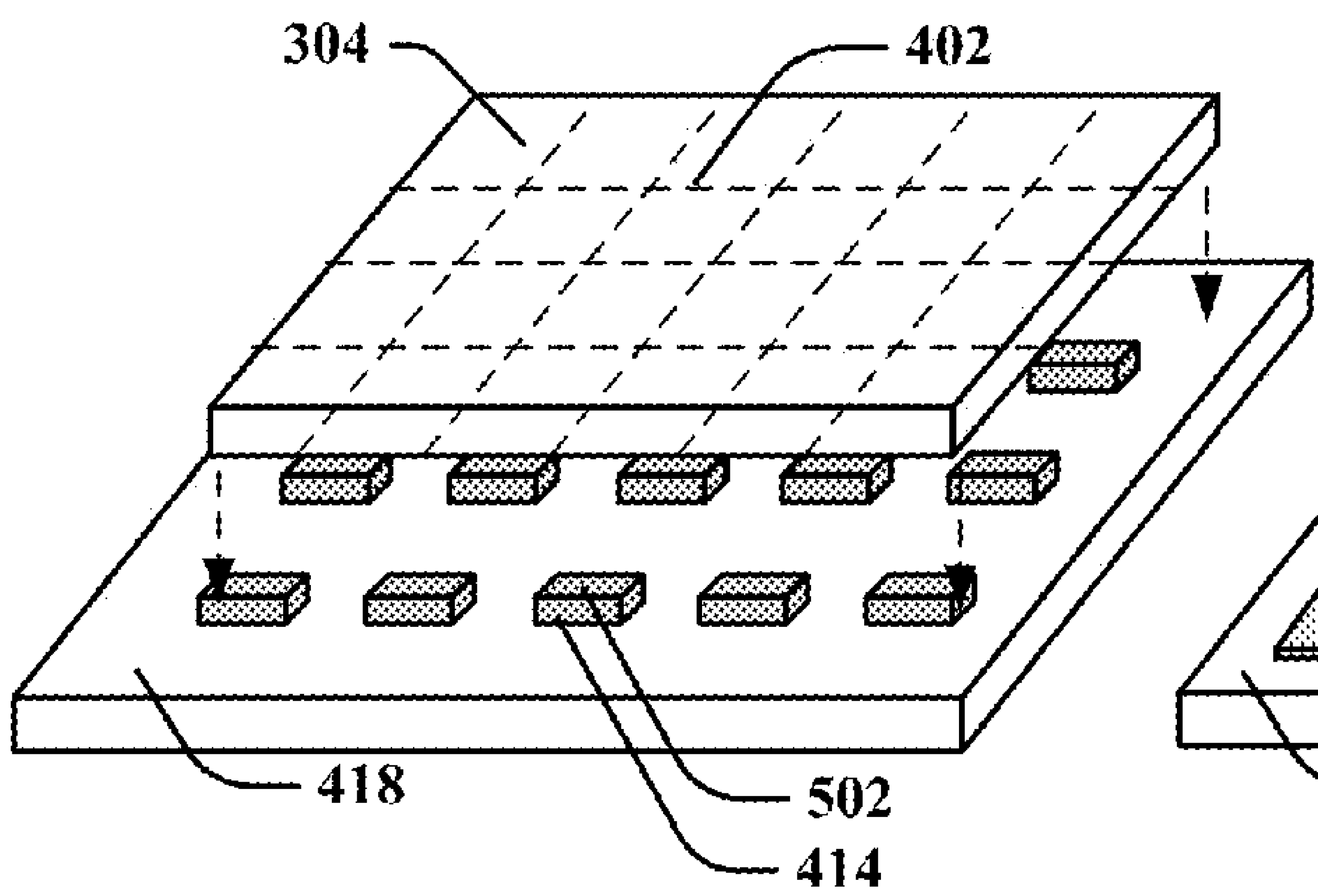

FIG. 5B

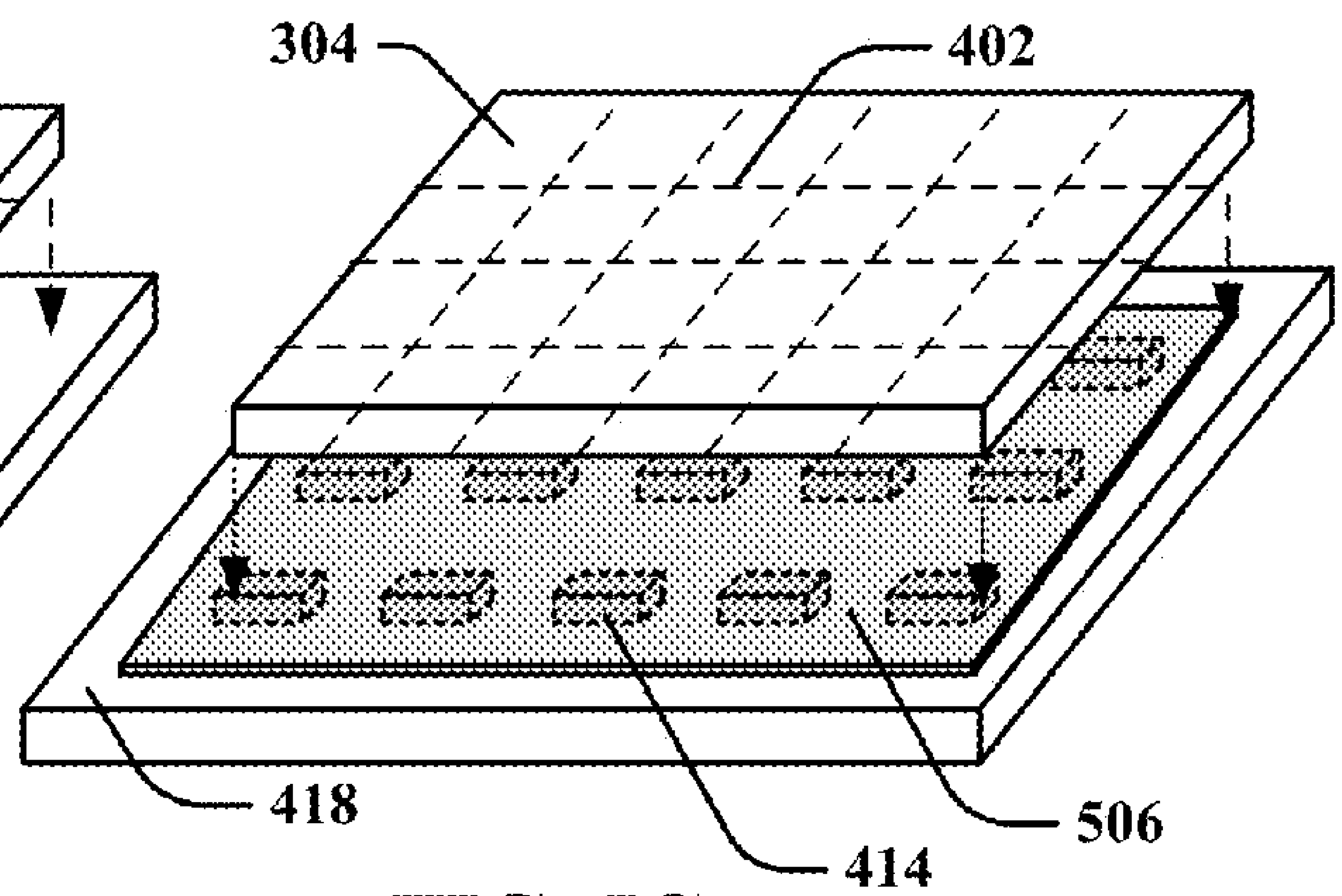

FIG. 5C

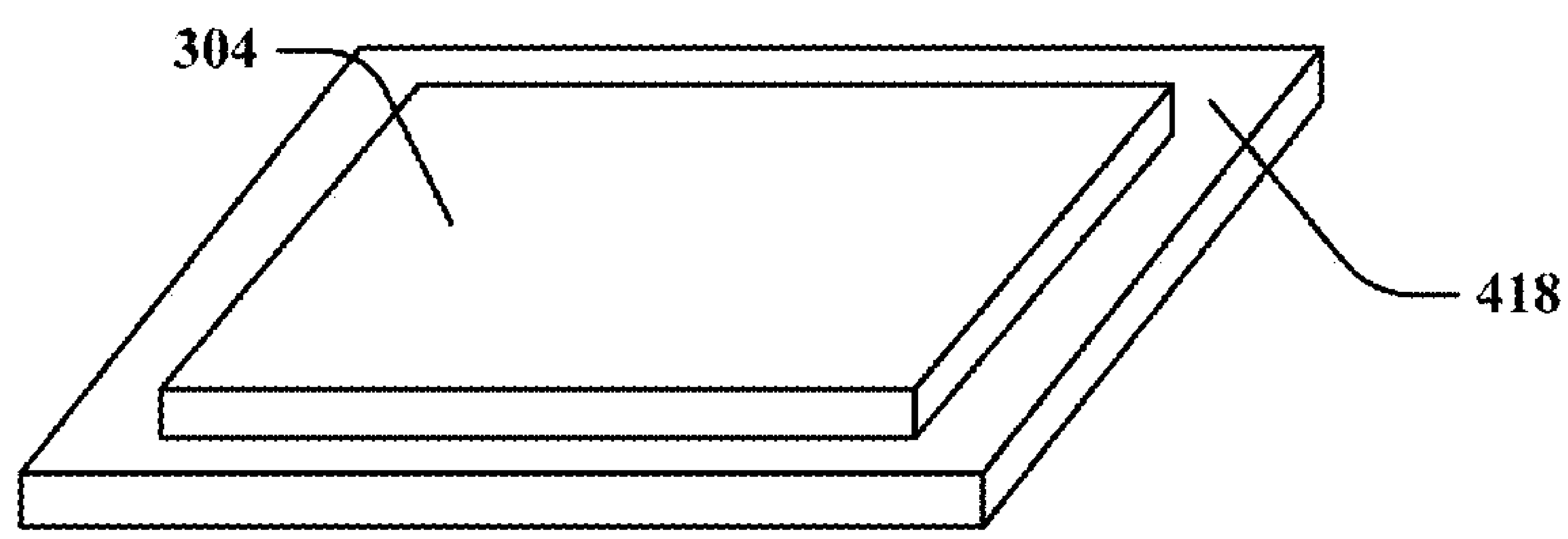

FIG. 5D

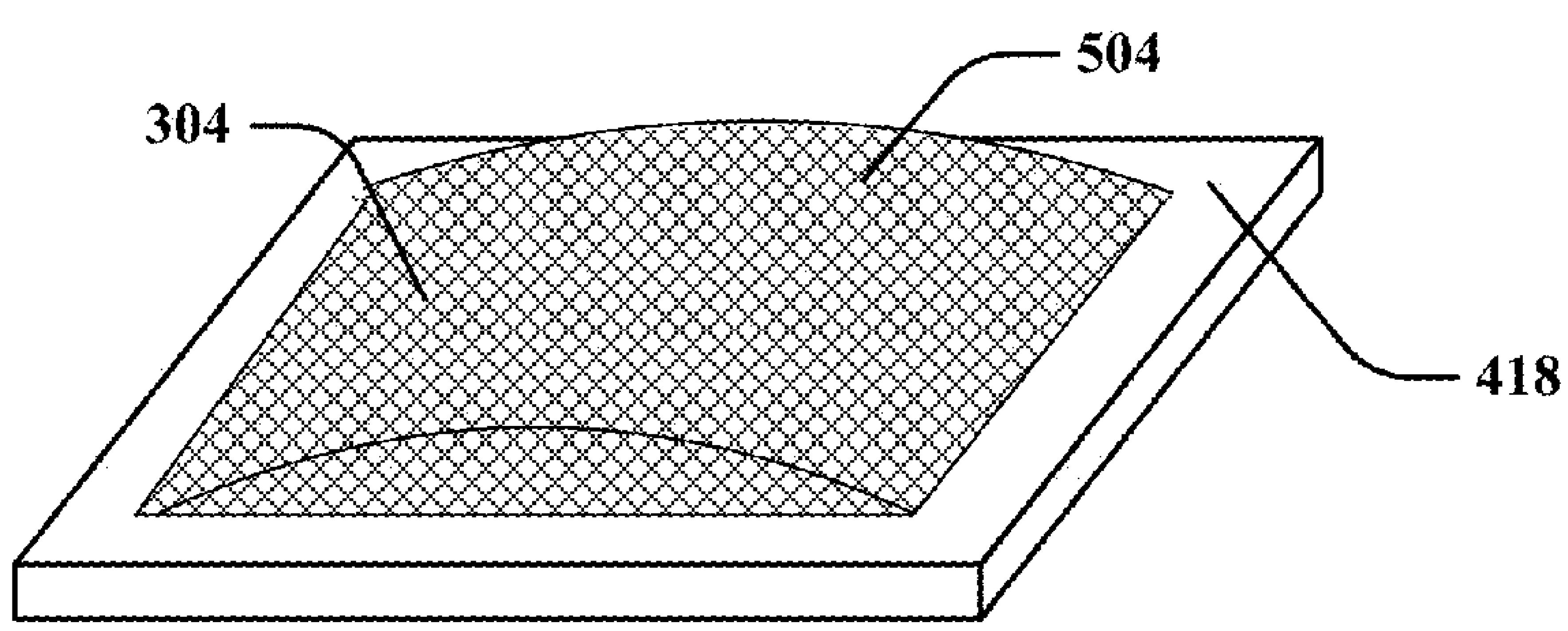

FIG. 5E

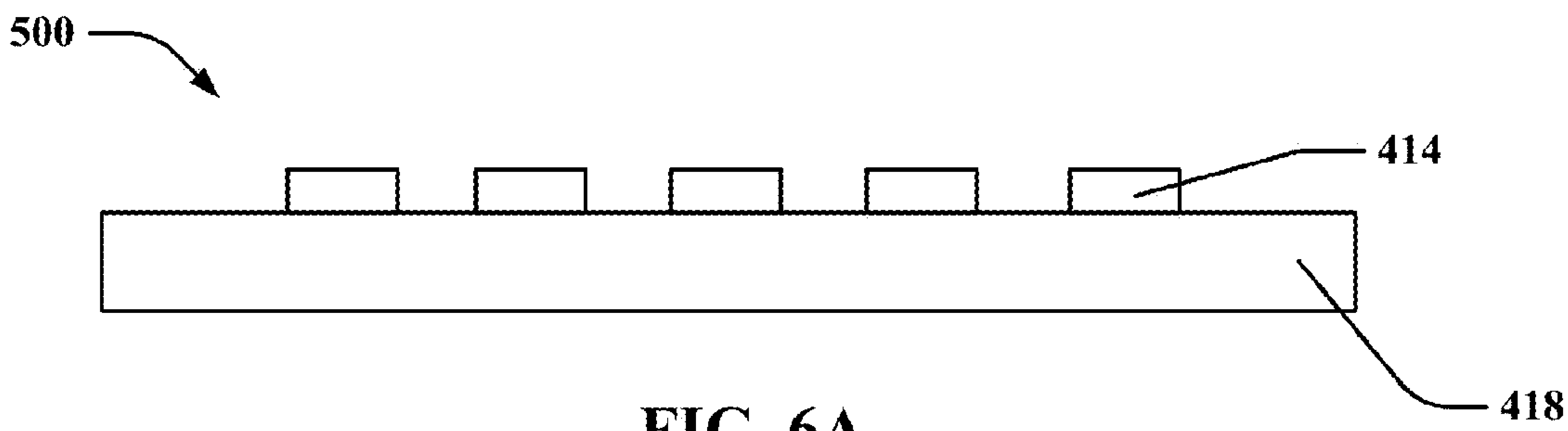

FIG. 6A

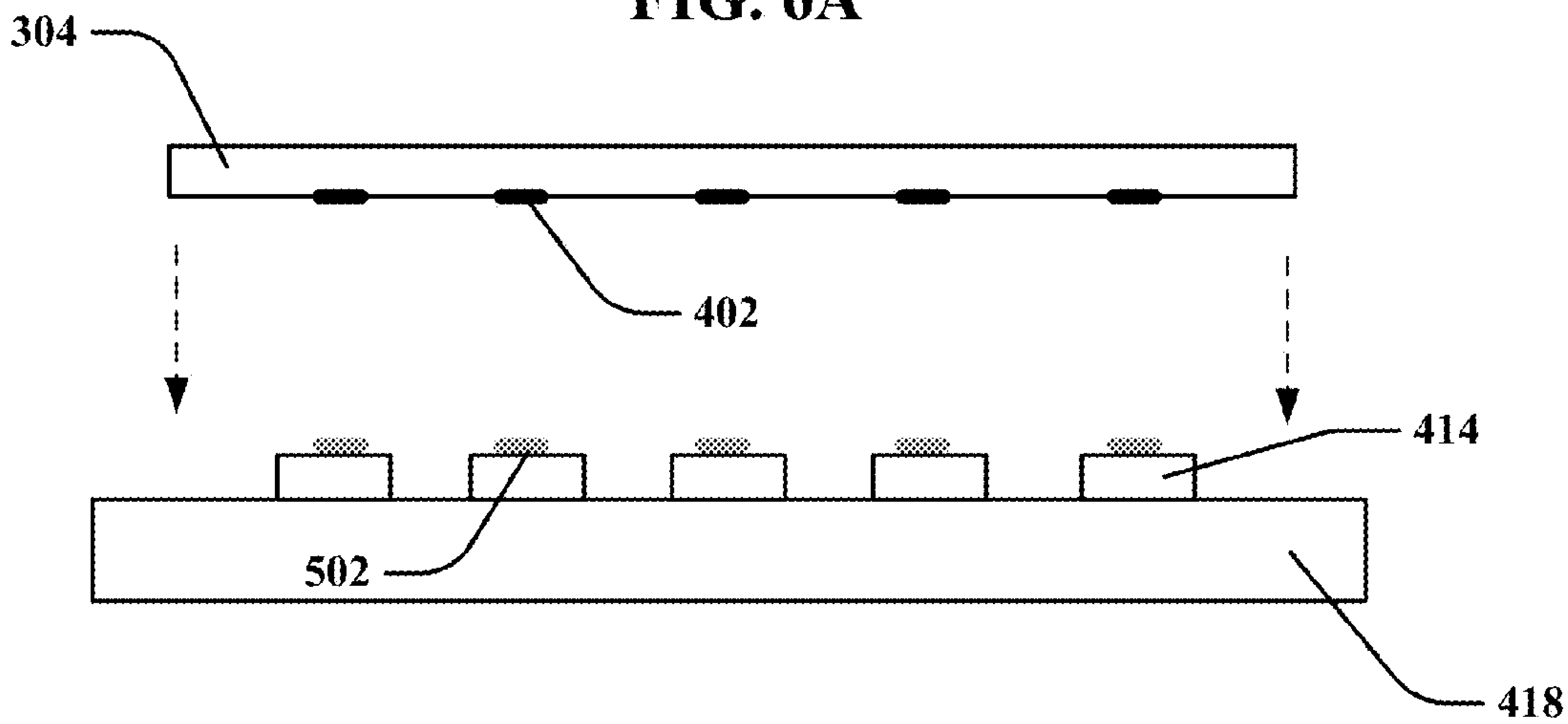

FIG. 6B

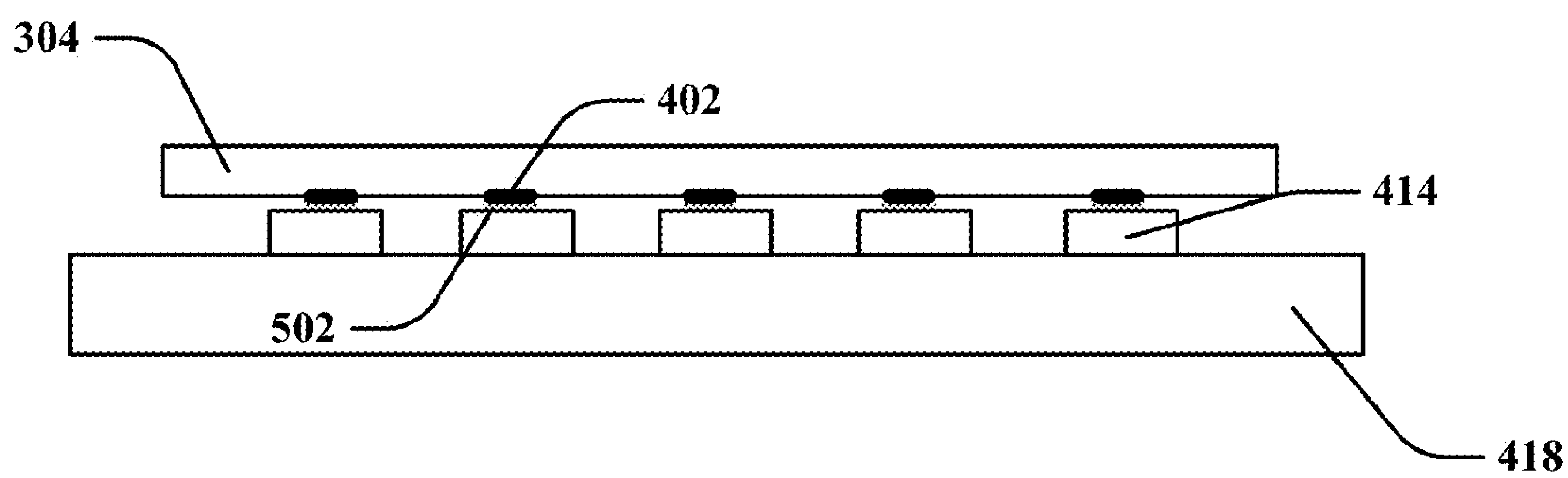

FIG. 6C

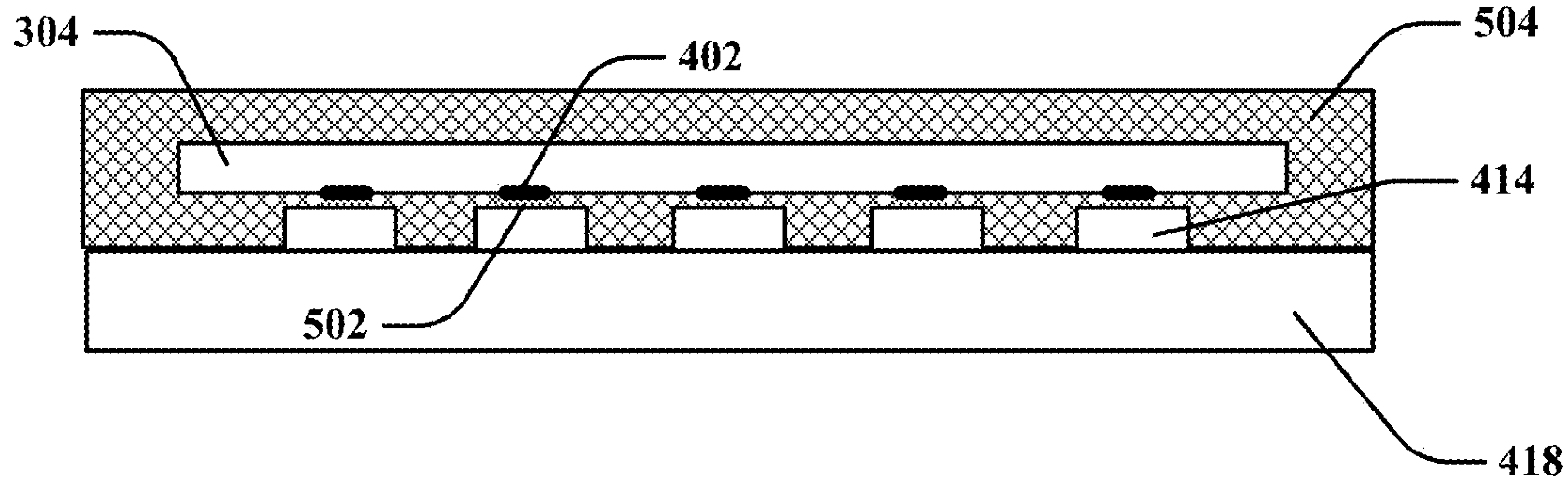

FIG. 6D

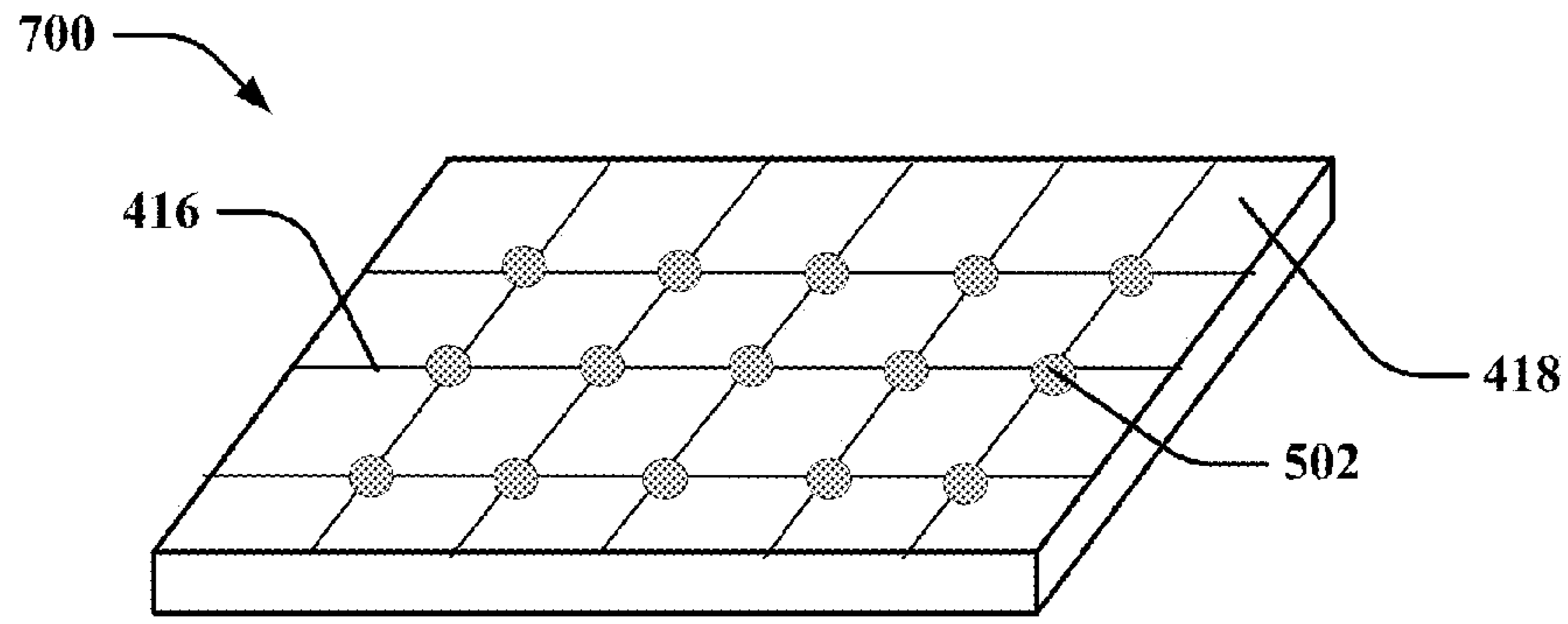

FIG. 7A

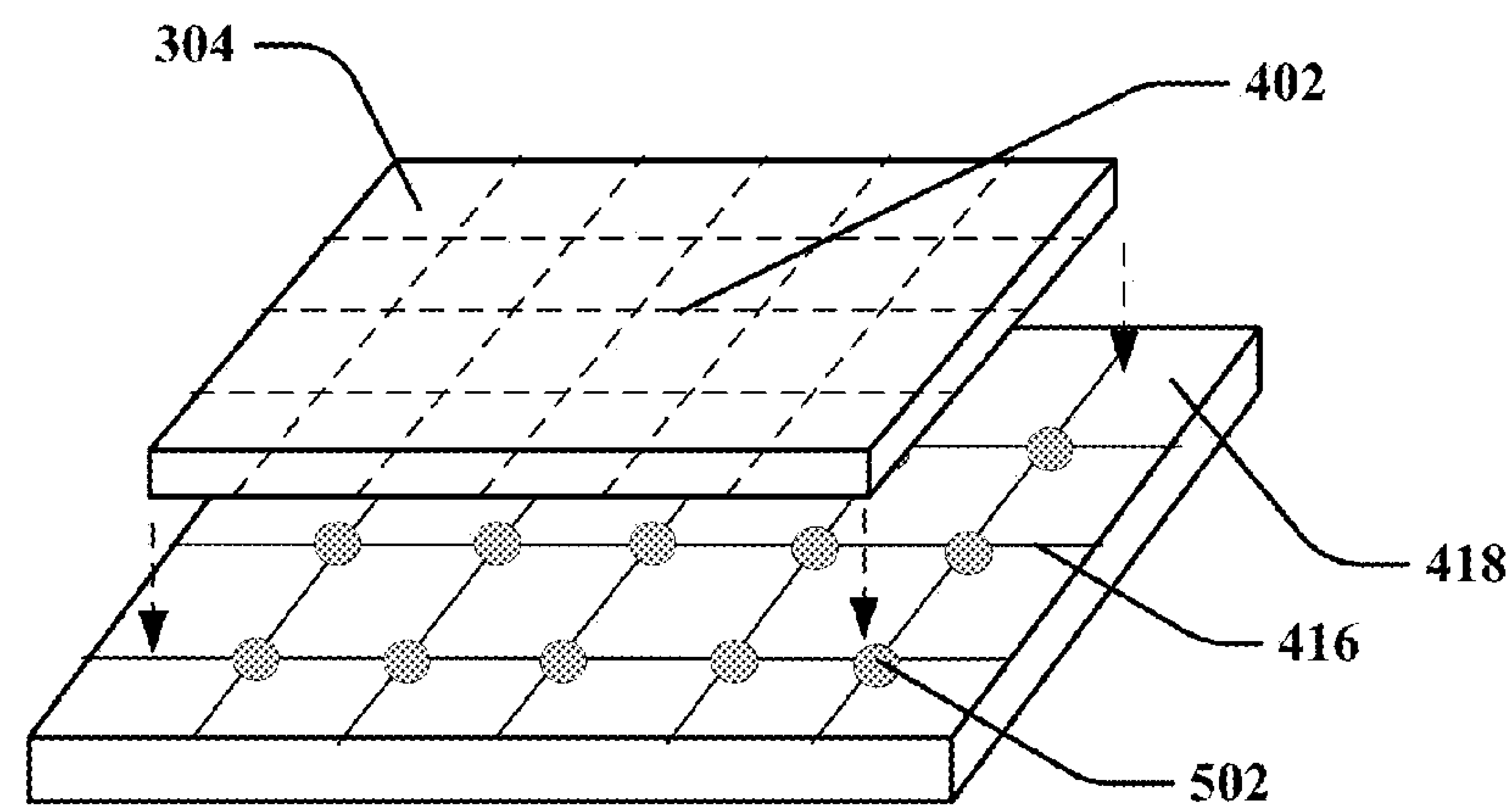

FIG. 7B

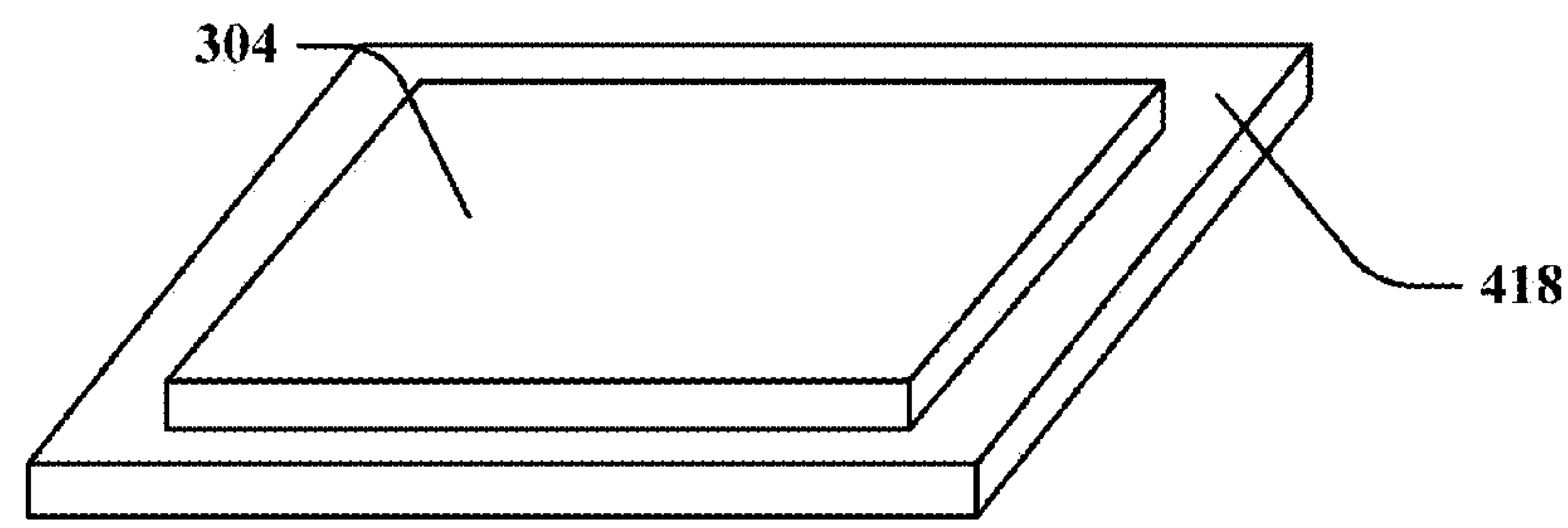

FIG. 7C

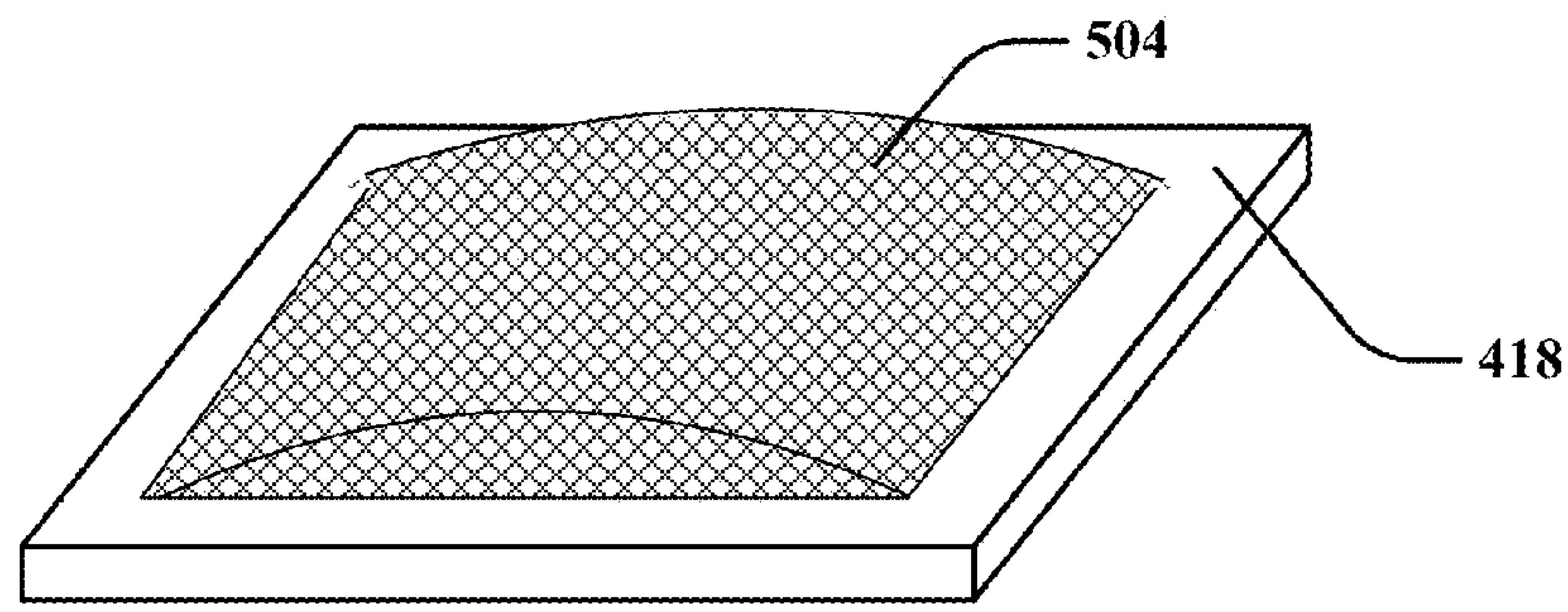

FIG. 7D

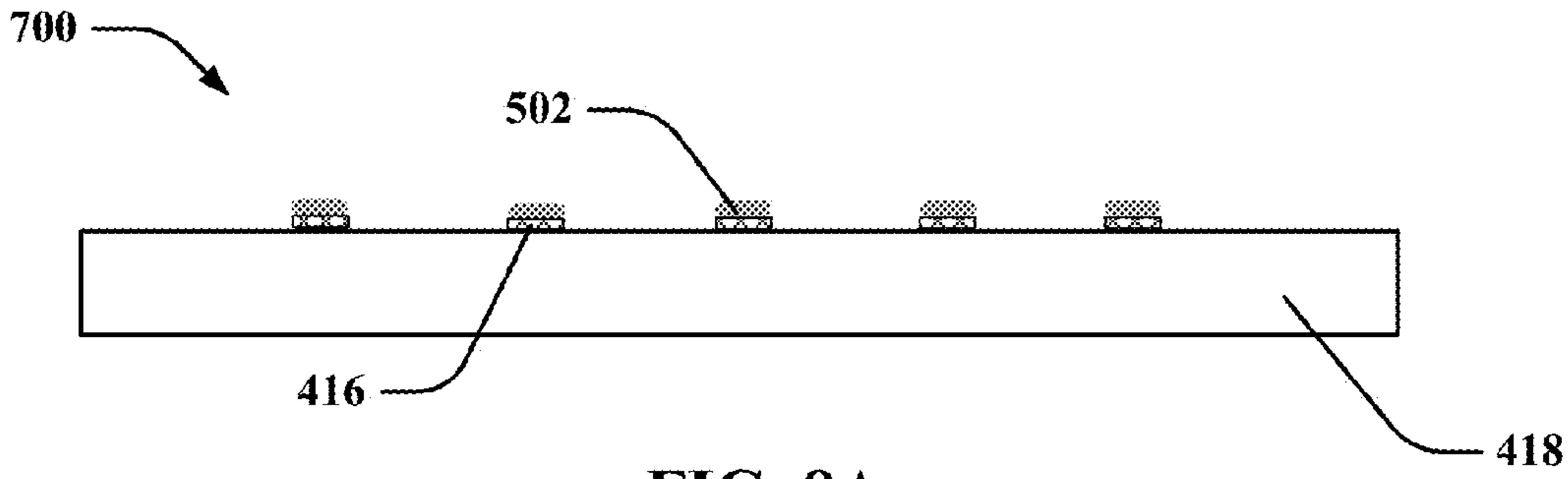

FIG. 8A

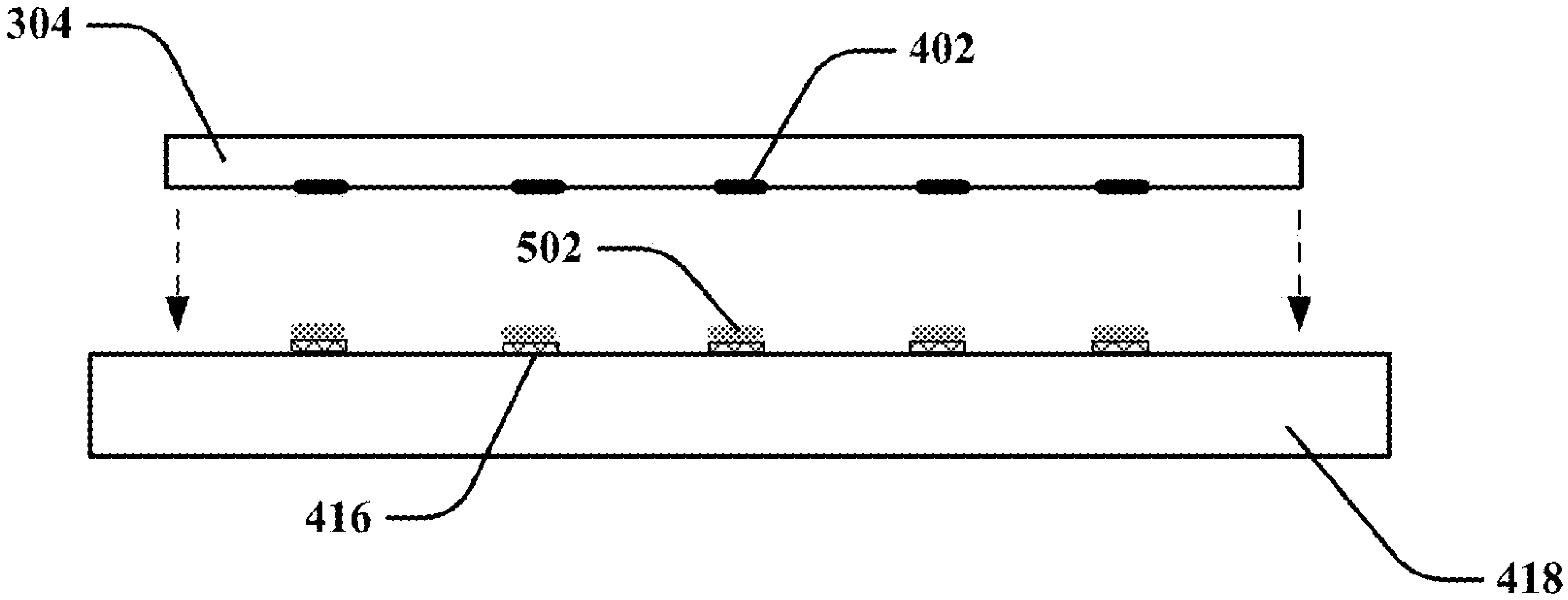

FIG. 8B

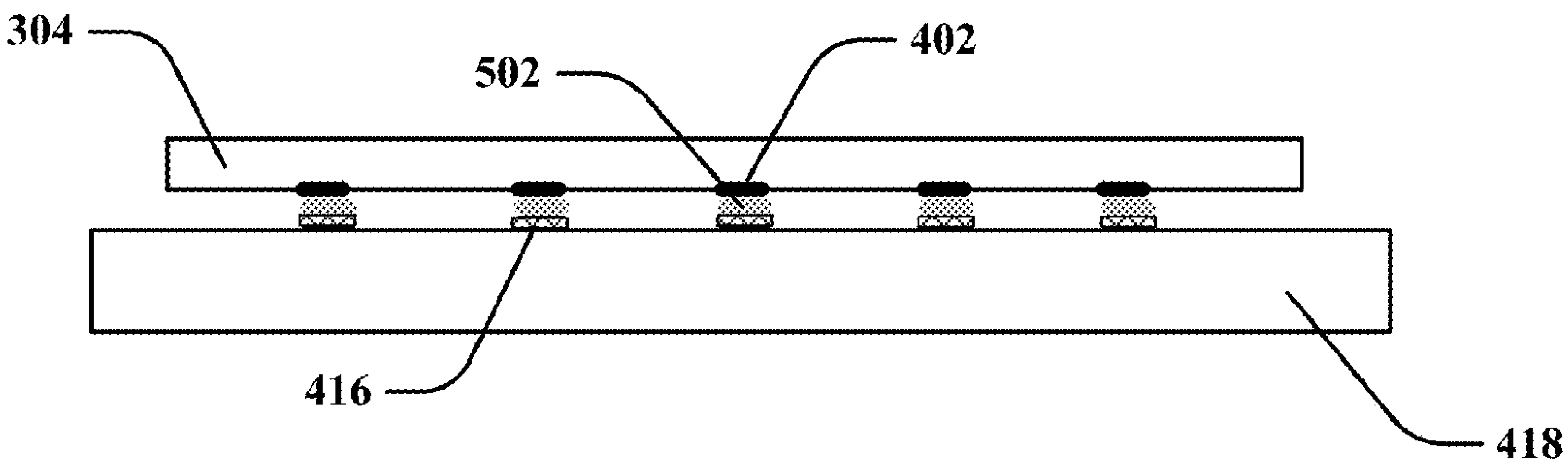

FIG. 8C

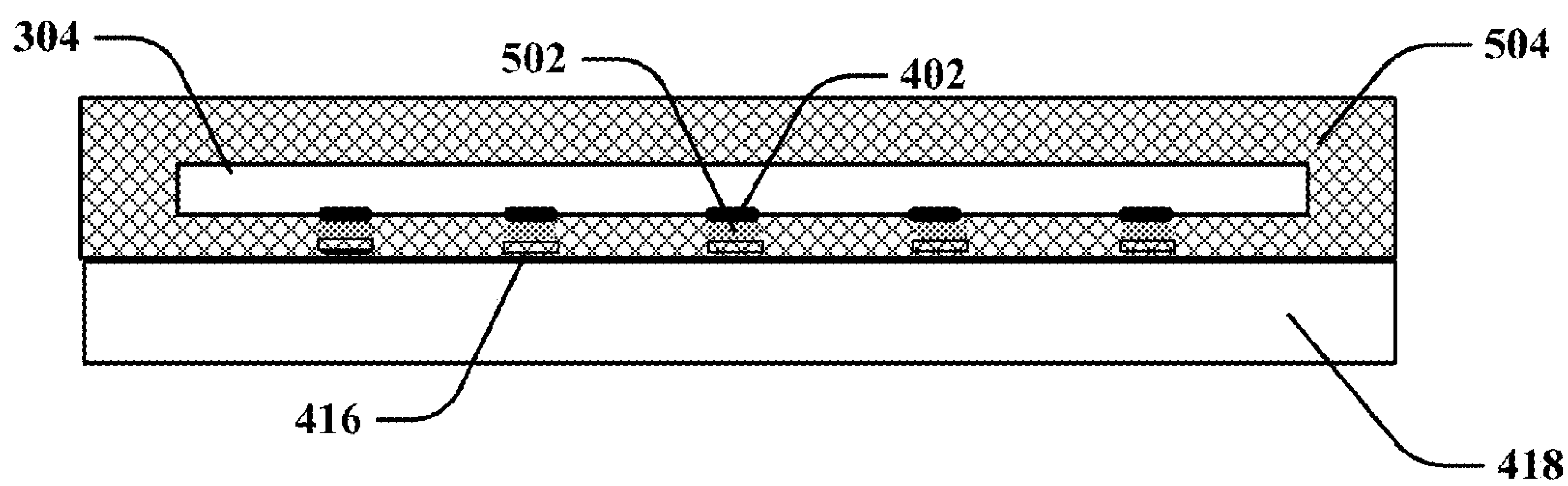

FIG. 8D

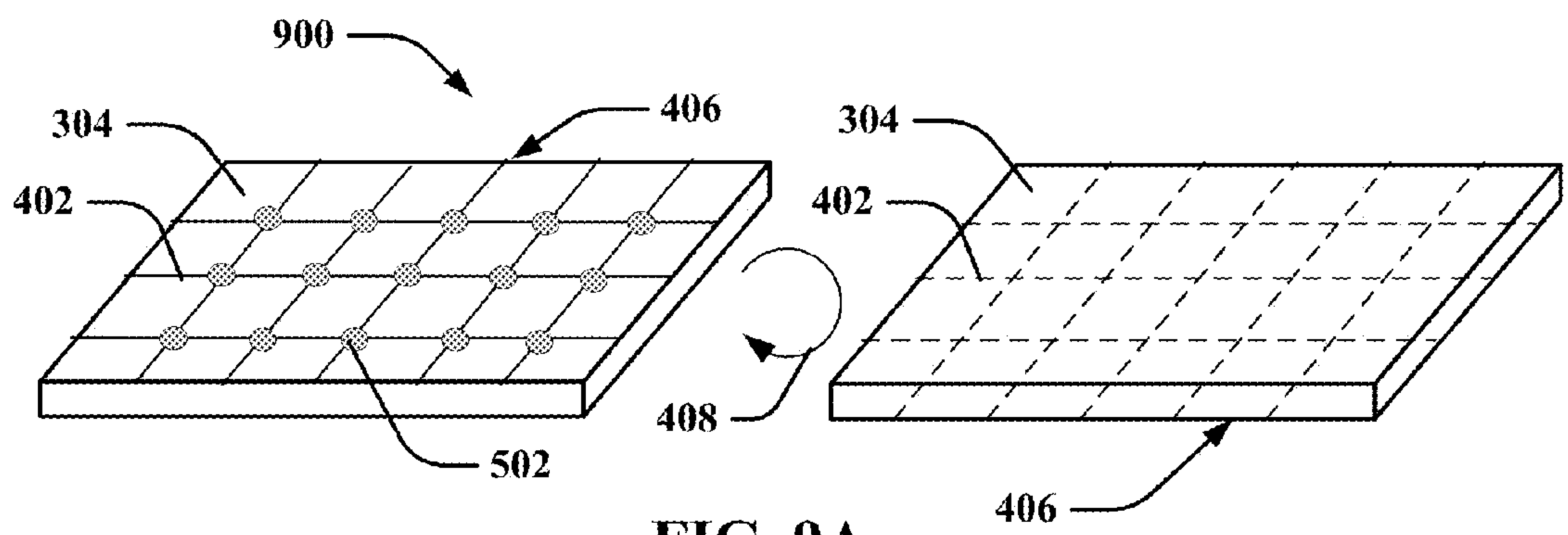

FIG. 9A

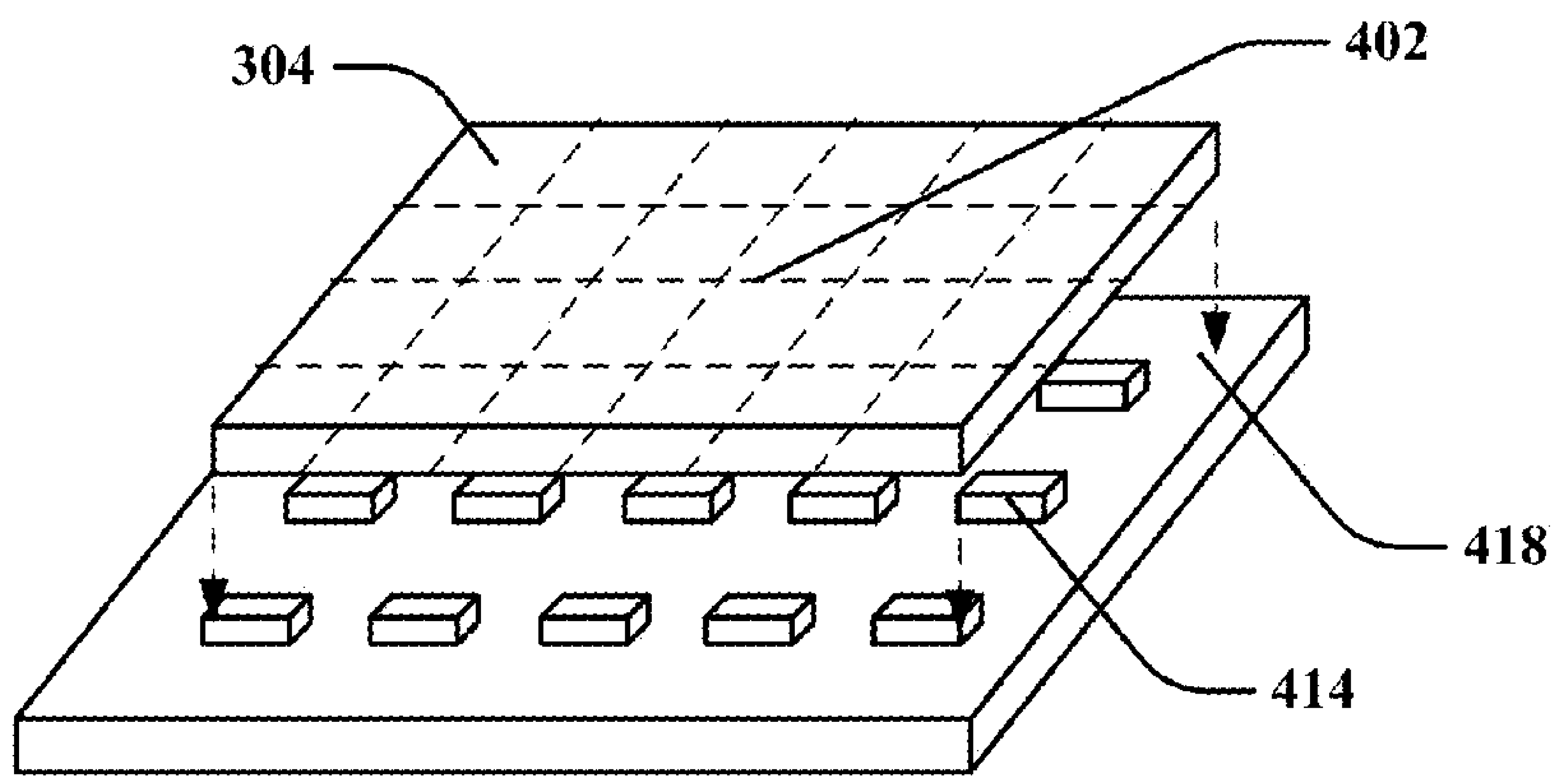

FIG. 9B

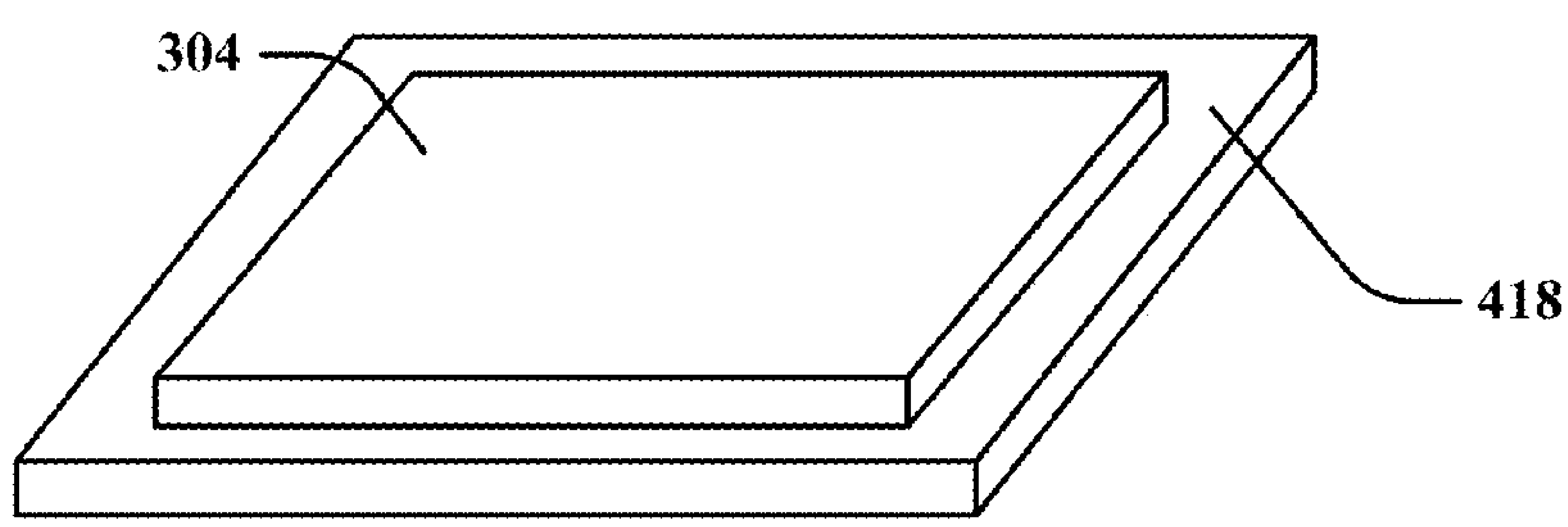

FIG. 9C

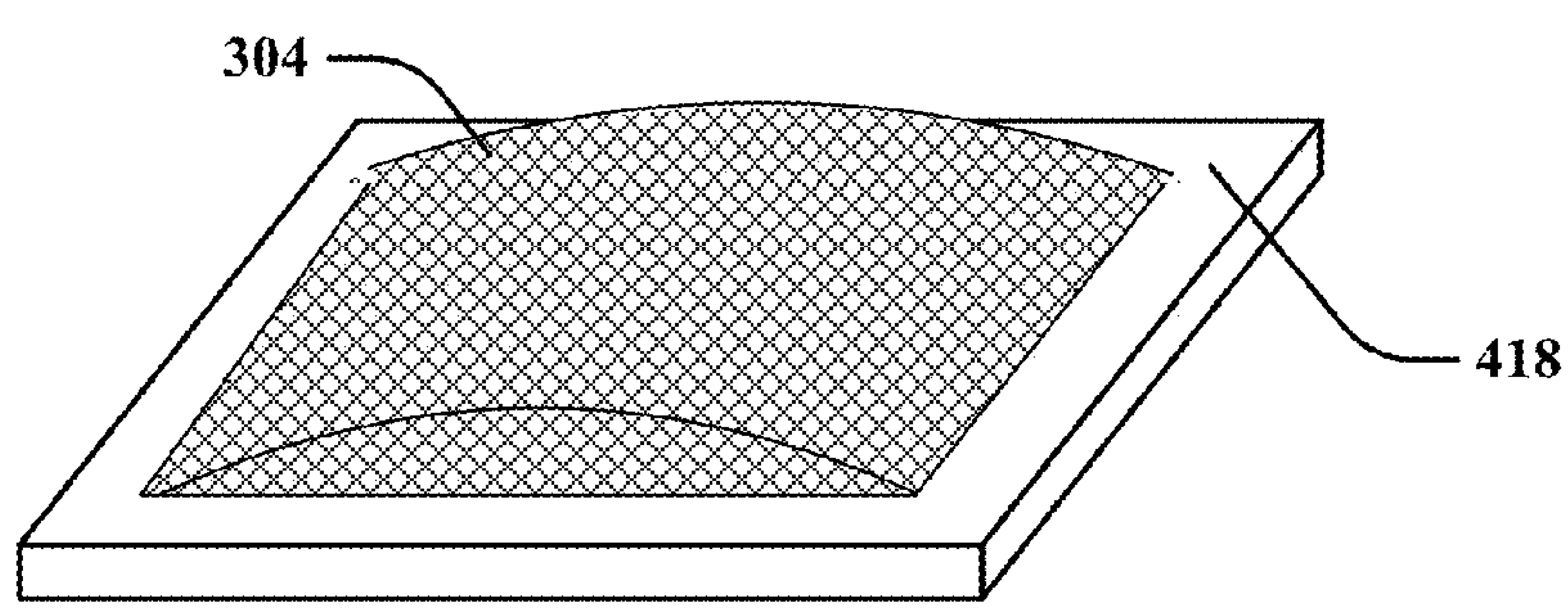

FIG. 9D

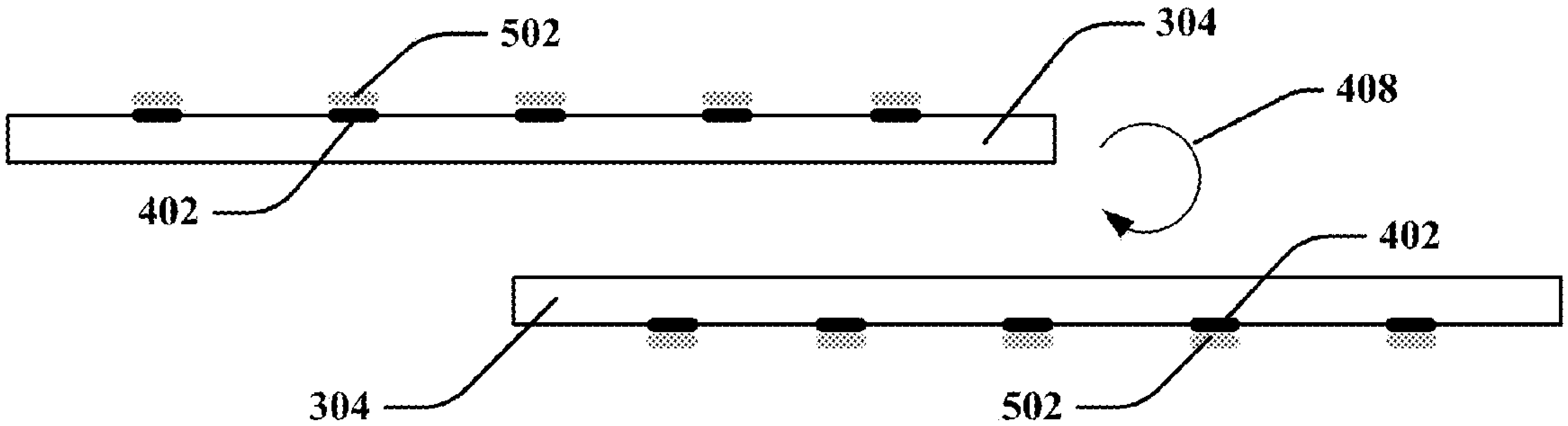

FIG. 10A

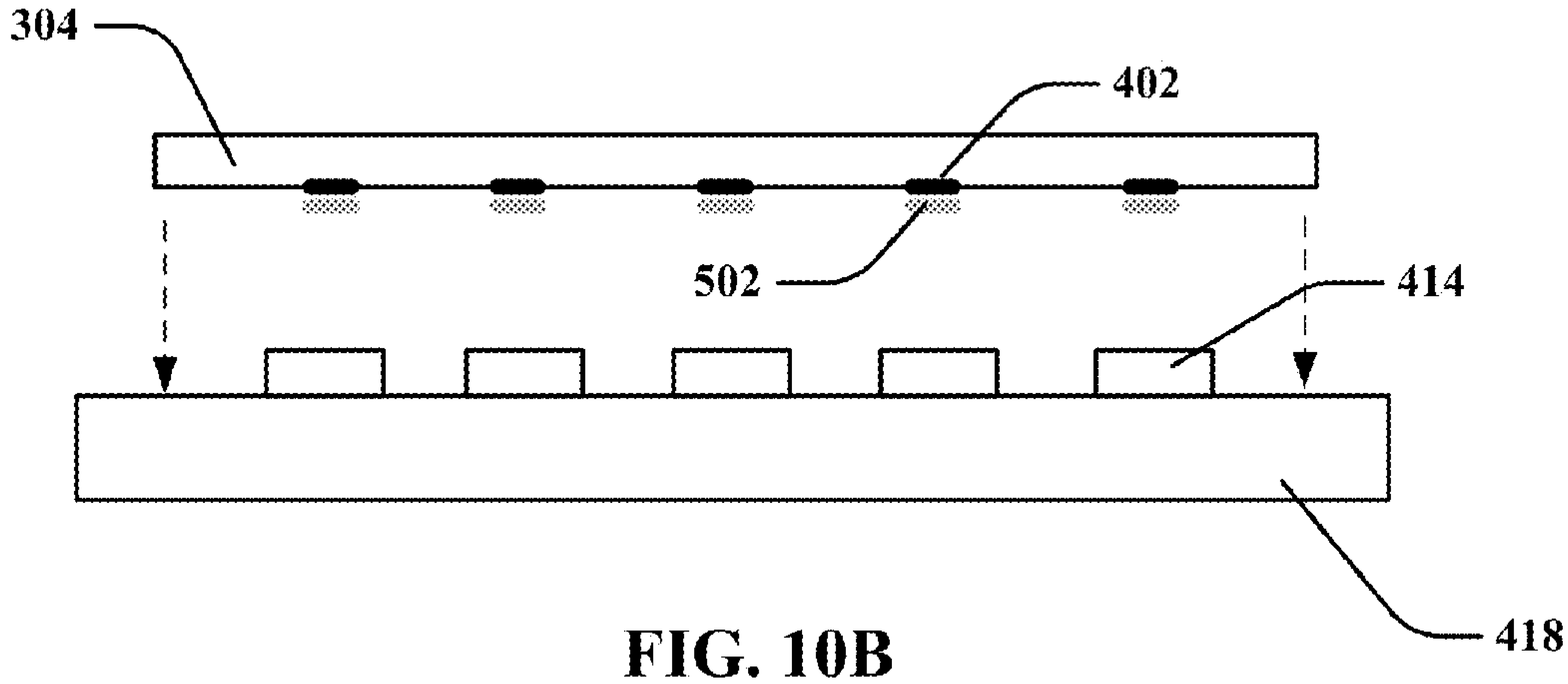

FIG. 10B

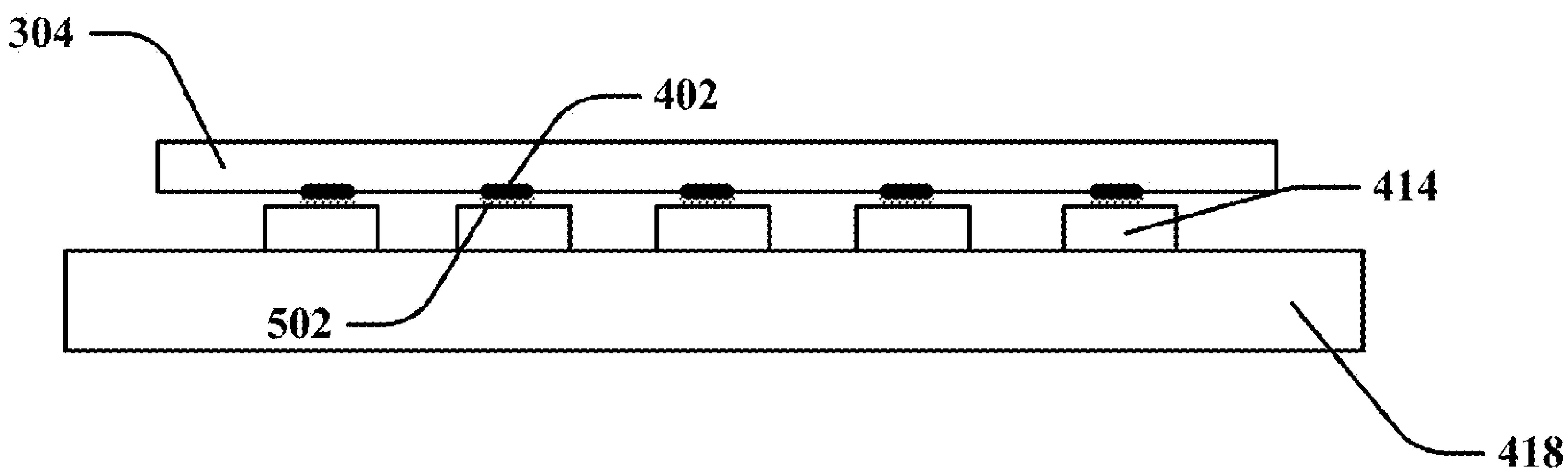

FIG. 10C

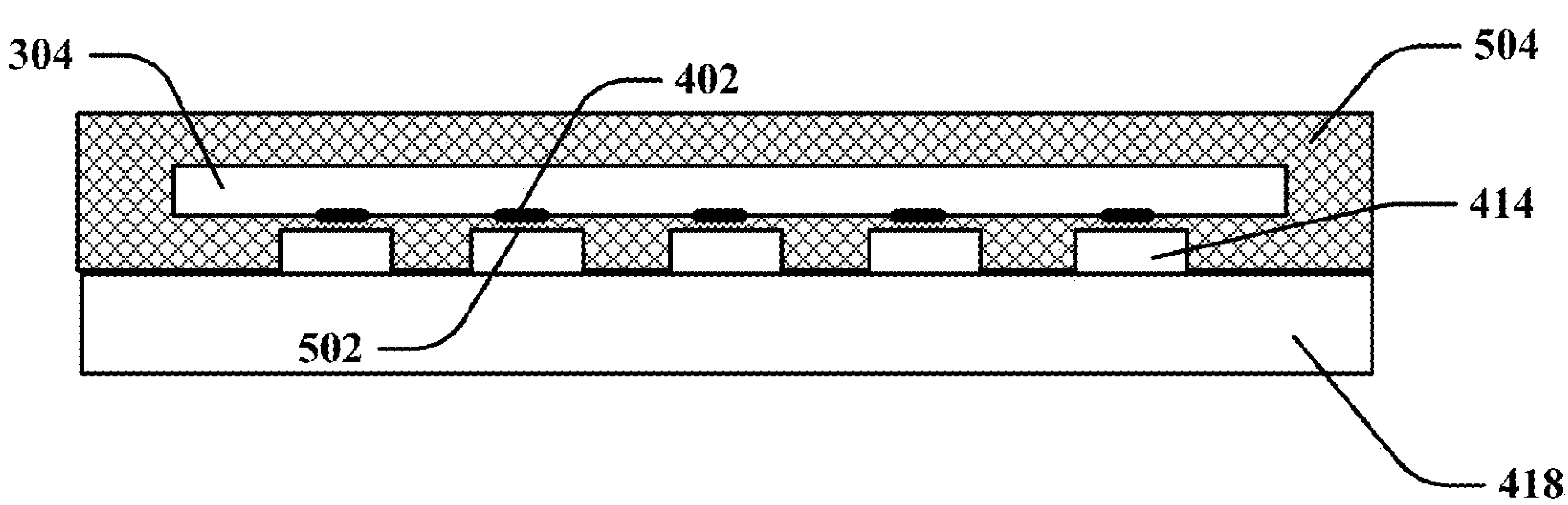

FIG. 10D

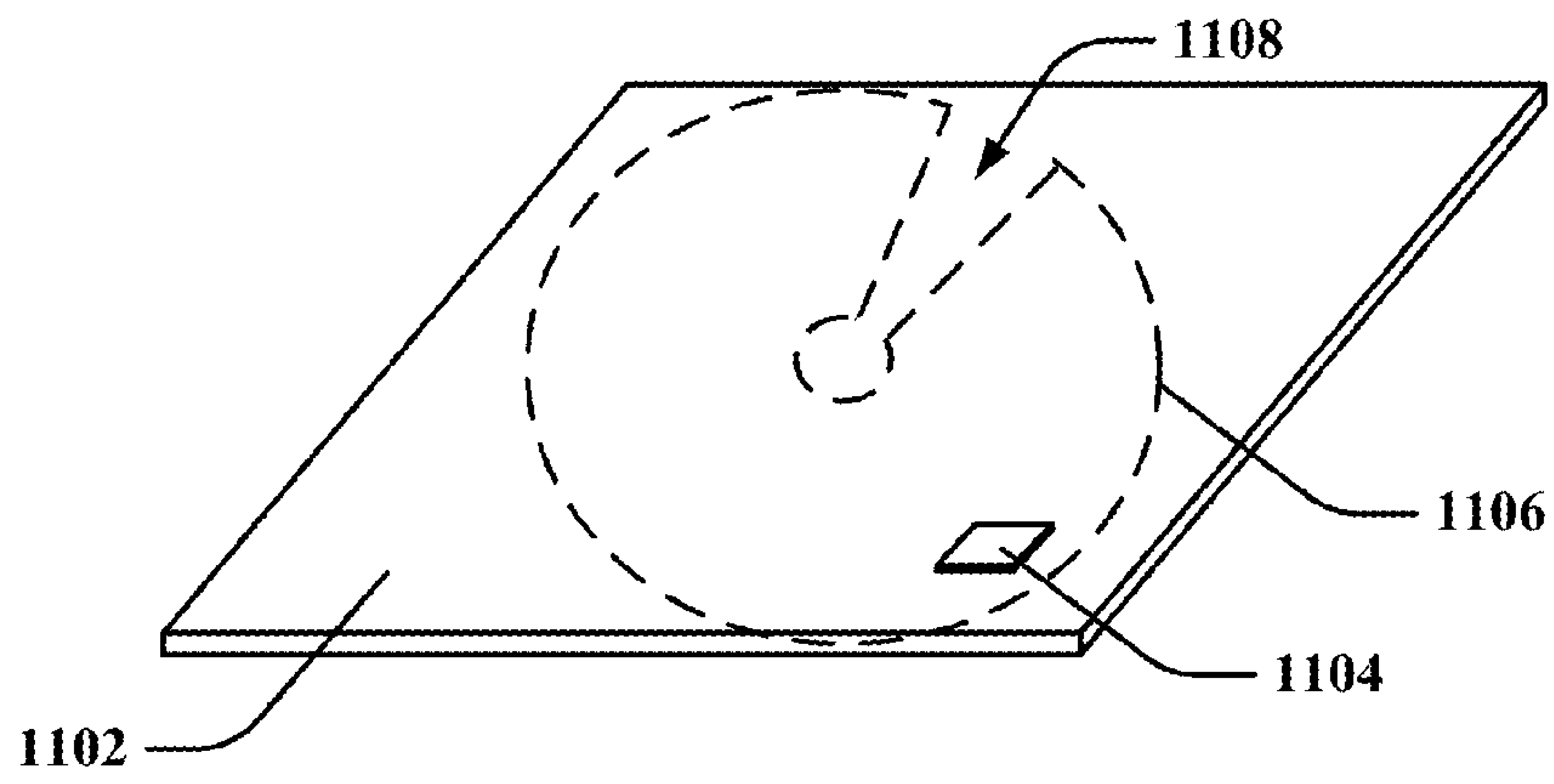

FIG. 11A

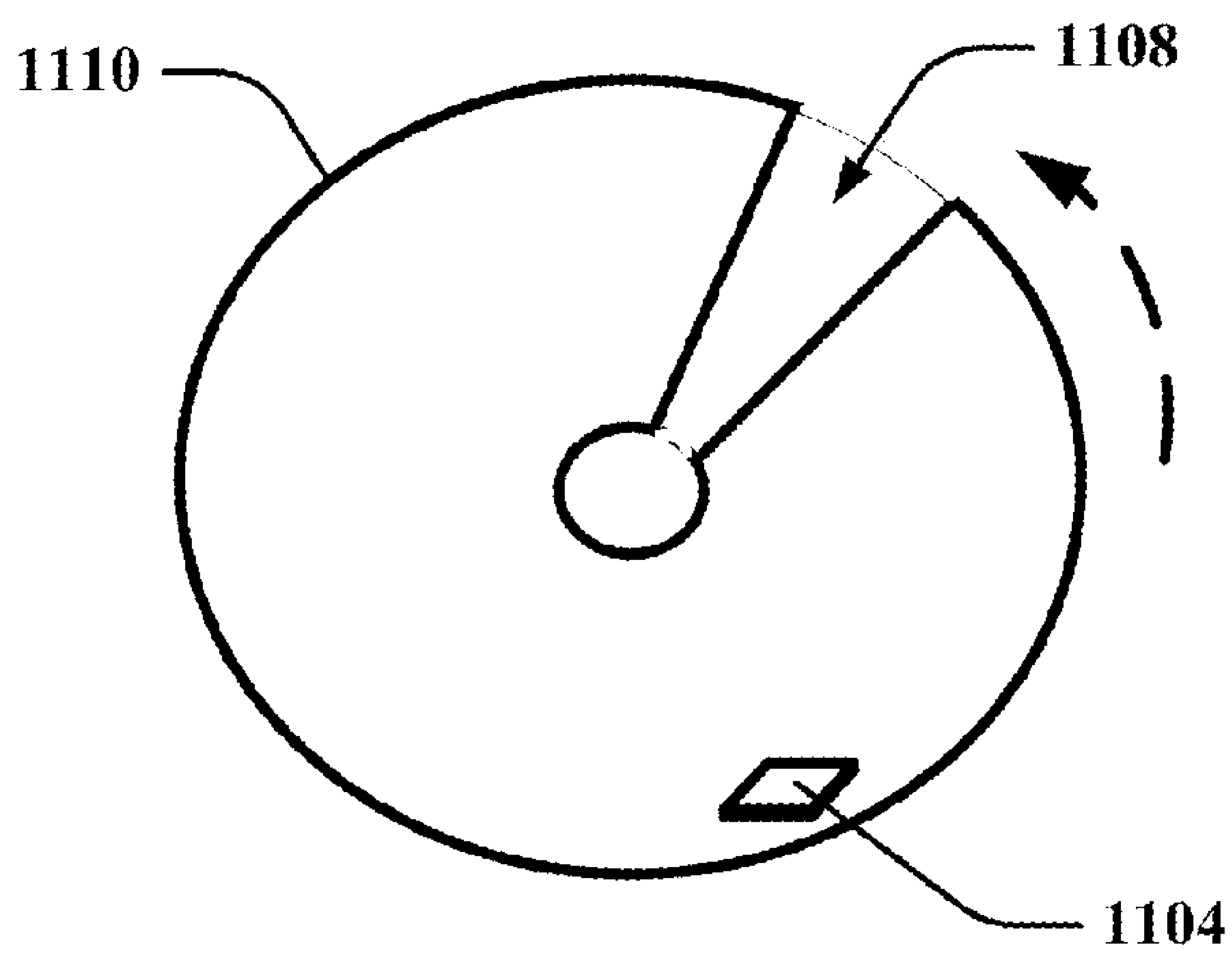

FIG. 11B

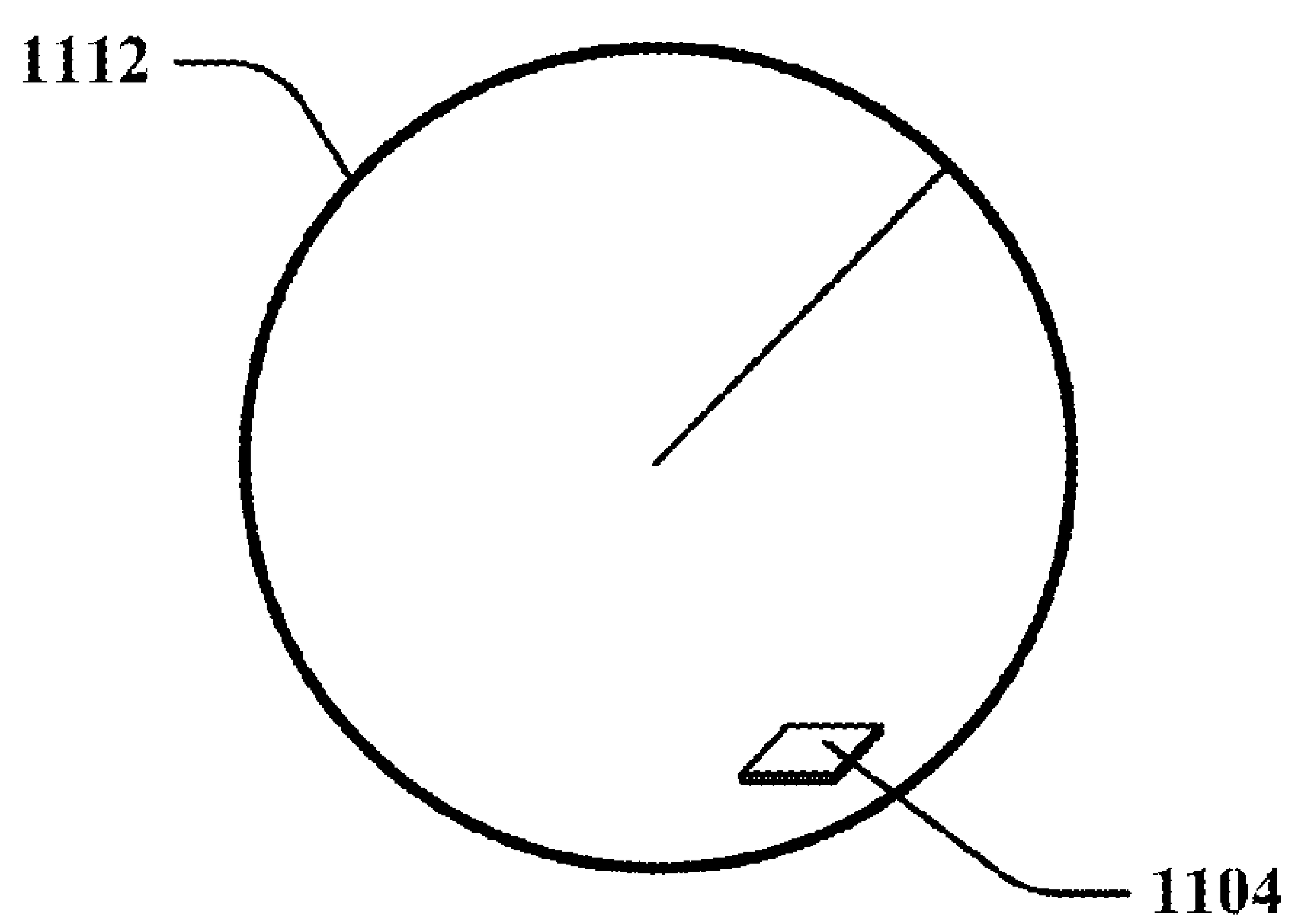

FIG. 11C

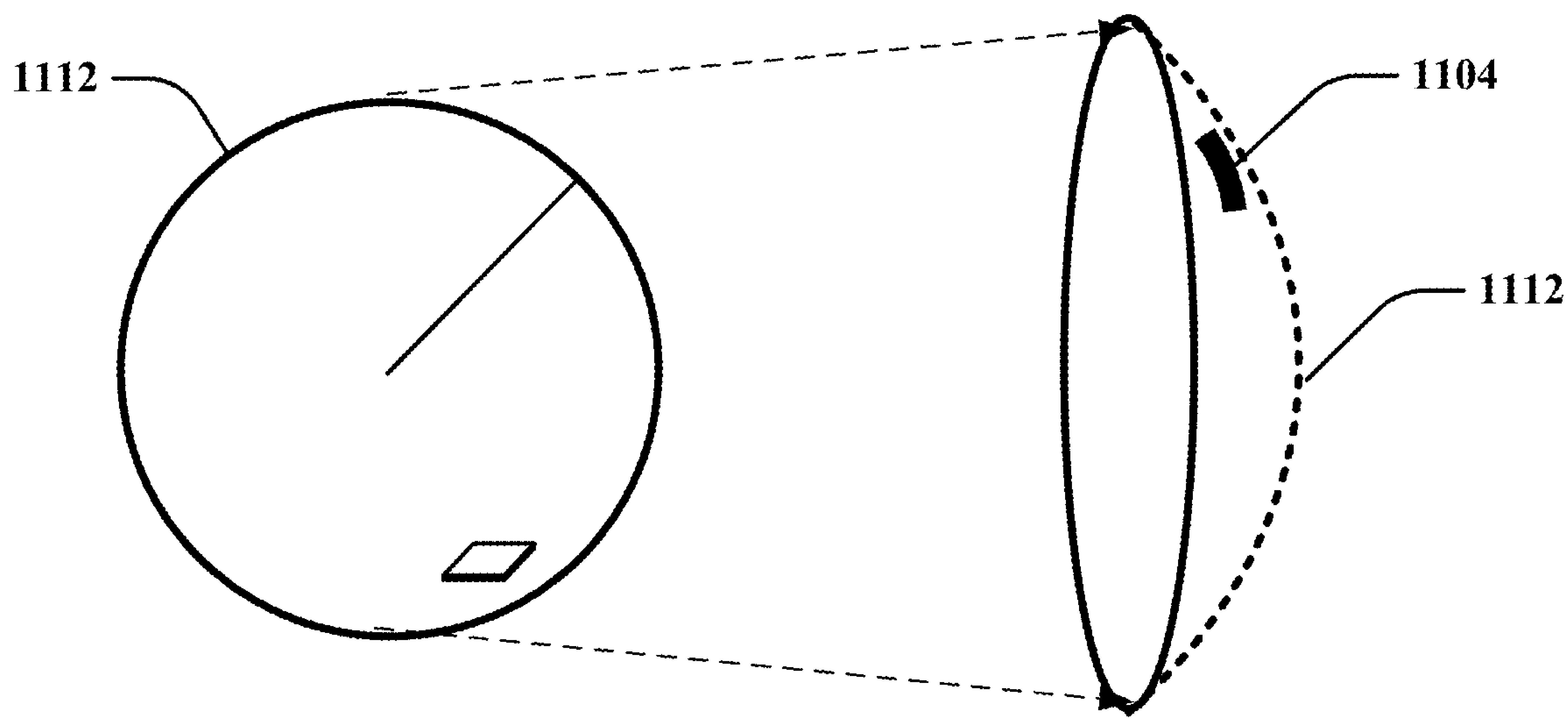

FIG. 12A

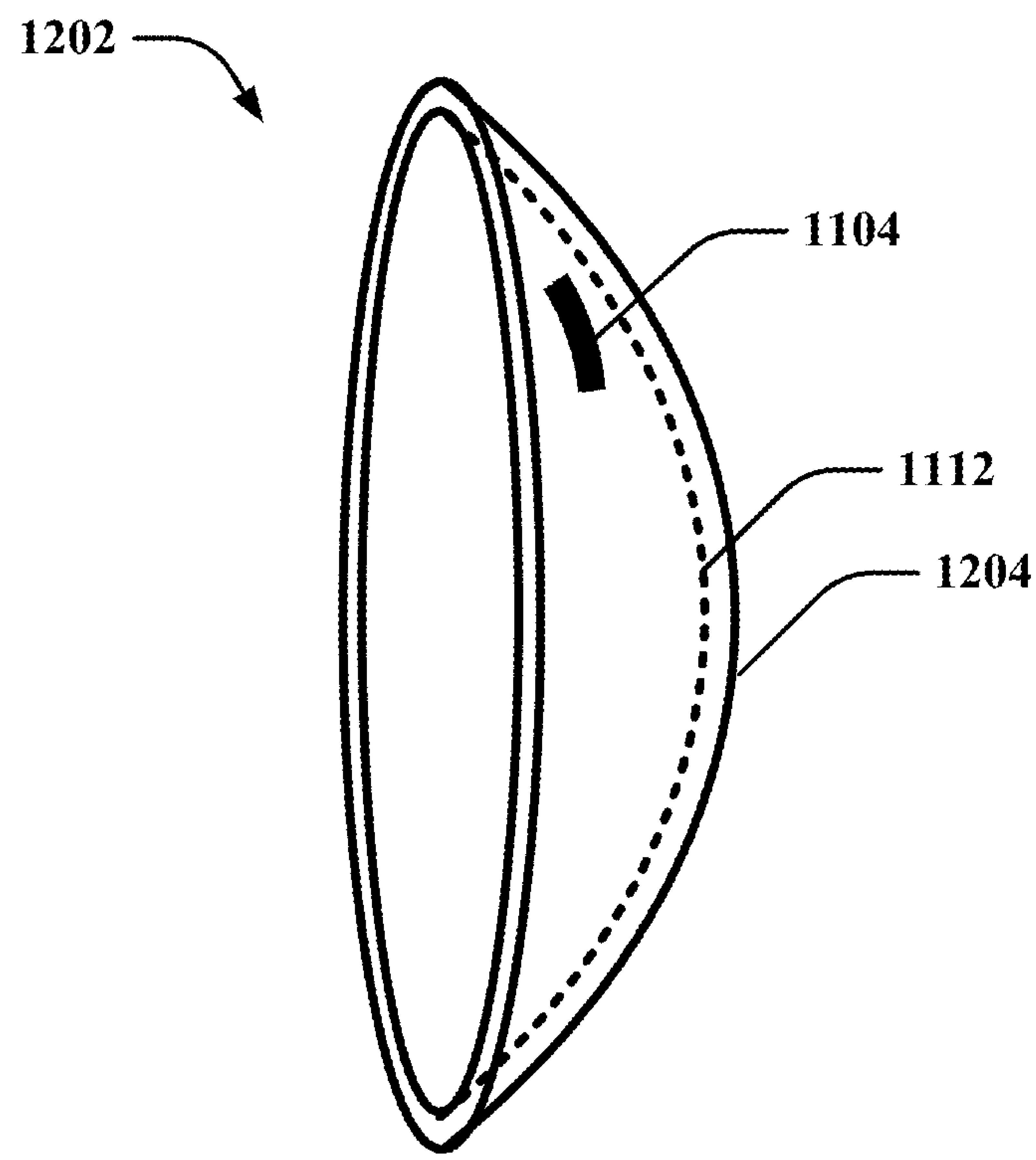

FIG. 12B

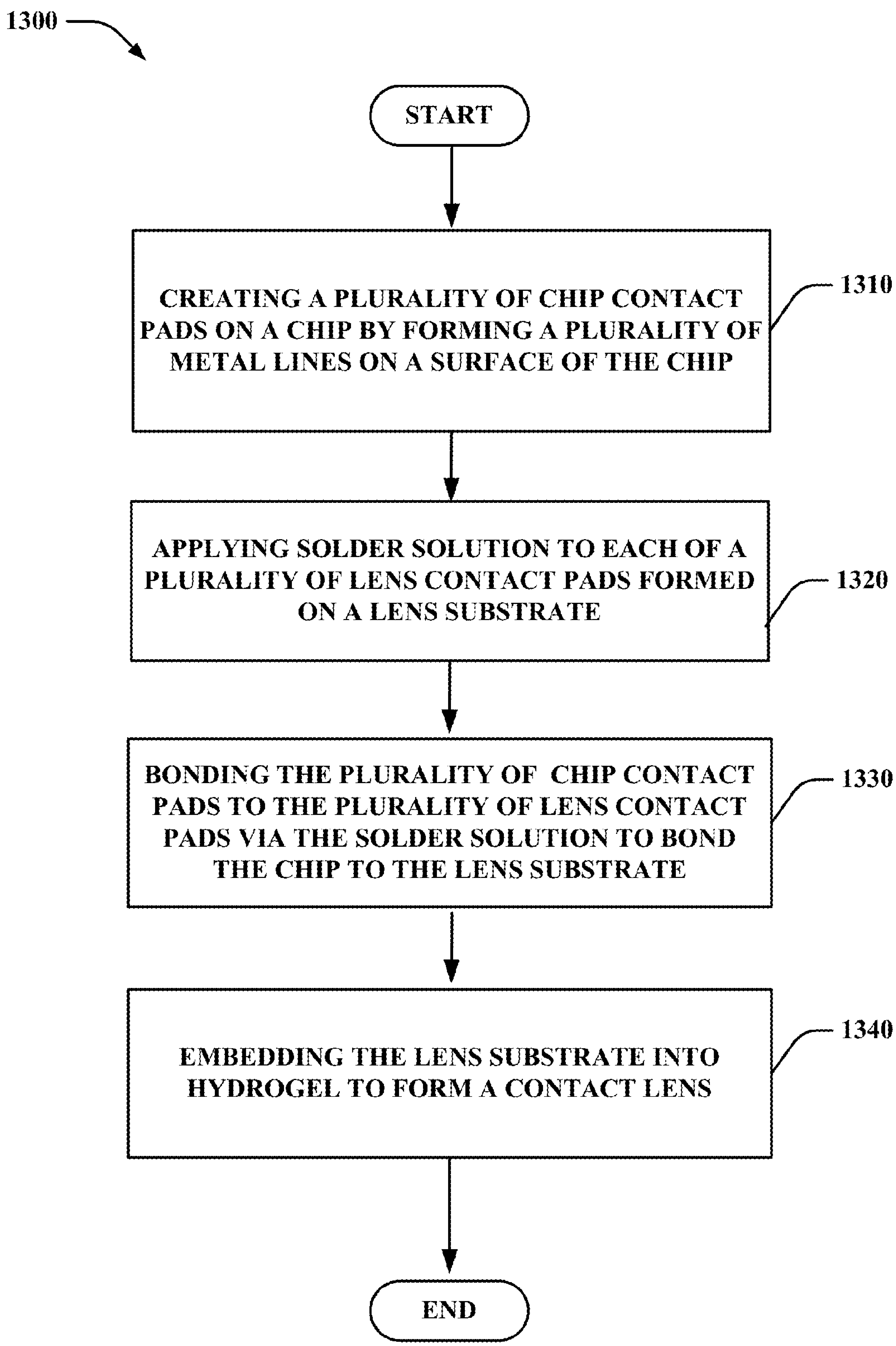
1300
START
CREATING A PLURALITY OF CHIP CONTACT PADS ON A CHIP BY FORMING A PLURALITY OF METAL LINES ON A SURFACE OF THE CHIP
1310
APPLYING SOLDER SOLUTION TO EACH OF A PLURALITY OF LENS CONTACT PADS FORMED ON A LENS SUBSTRATE
1320
BONDING THE PLURALITY OF CHIP CONTACT PADS TO THE PLURALITY OF LENS CONTACT PADS VIA THE SOLDER SOLUTION TO BOND THE CHIP TO THE LENS SUBSTRATE
1330
EMBEDDING THE LENS SUBSTRATE INTO HYDROGEL TO FORM A CONTACT LENS
1340
END

FIG. 13

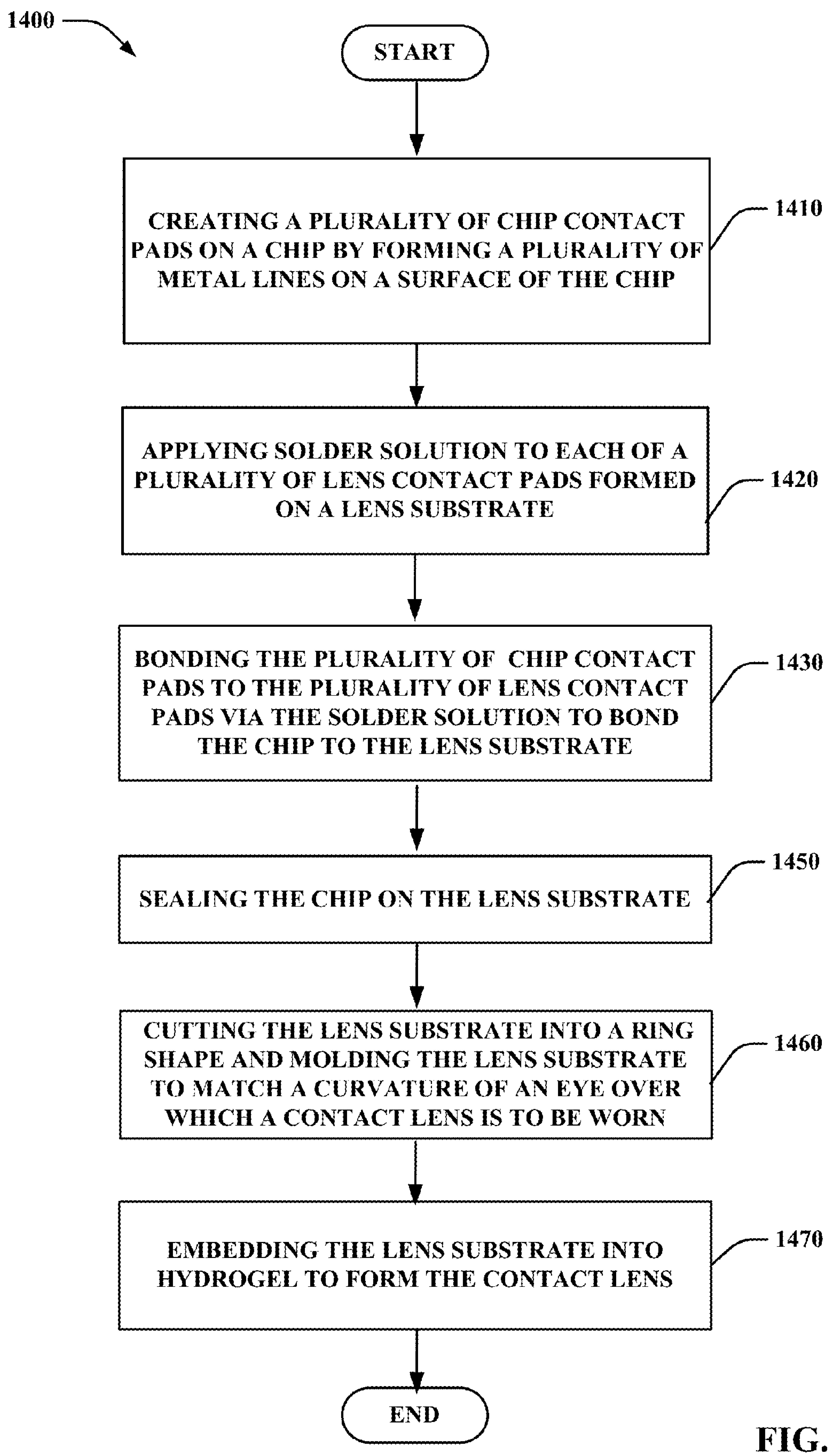
1400
START
CREATING A PLURALITY OF CHIP CONTACT PADS ON A CHIP BY FORMING A PLURALITY OF METAL LINES ON A SURFACE OF THE CHIP
1410
APPLYING SOLDER SOLUTION TO EACH OF A PLURALITY OF LENS CONTACT PADS FORMED ON A LENS SUBSTRATE
1420
BONDING THE PLURALITY OF CHIP CONTACT PADS TO THE PLURALITY OF LENS CONTACT PADS VIA THE SOLDER SOLUTION TO BOND THE CHIP TO THE LENS SUBSTRATE
1430
SEALING THE CHIP ON THE LENS SUBSTRATE
1450
CUTTING THE LENS SUBSTRATE INTO A RING SHAPE AND MOLDING THE LENS SUBSTRATE TO MATCH A CURVATURE OF AN EYE OVER WHICH A CONTACT LENS IS TO BE WORN
1460
EMBEDDING THE LENS SUBSTRATE INTO HYDROGEL TO FORM THE CONTACT LENS
1470
END

FIG. 14

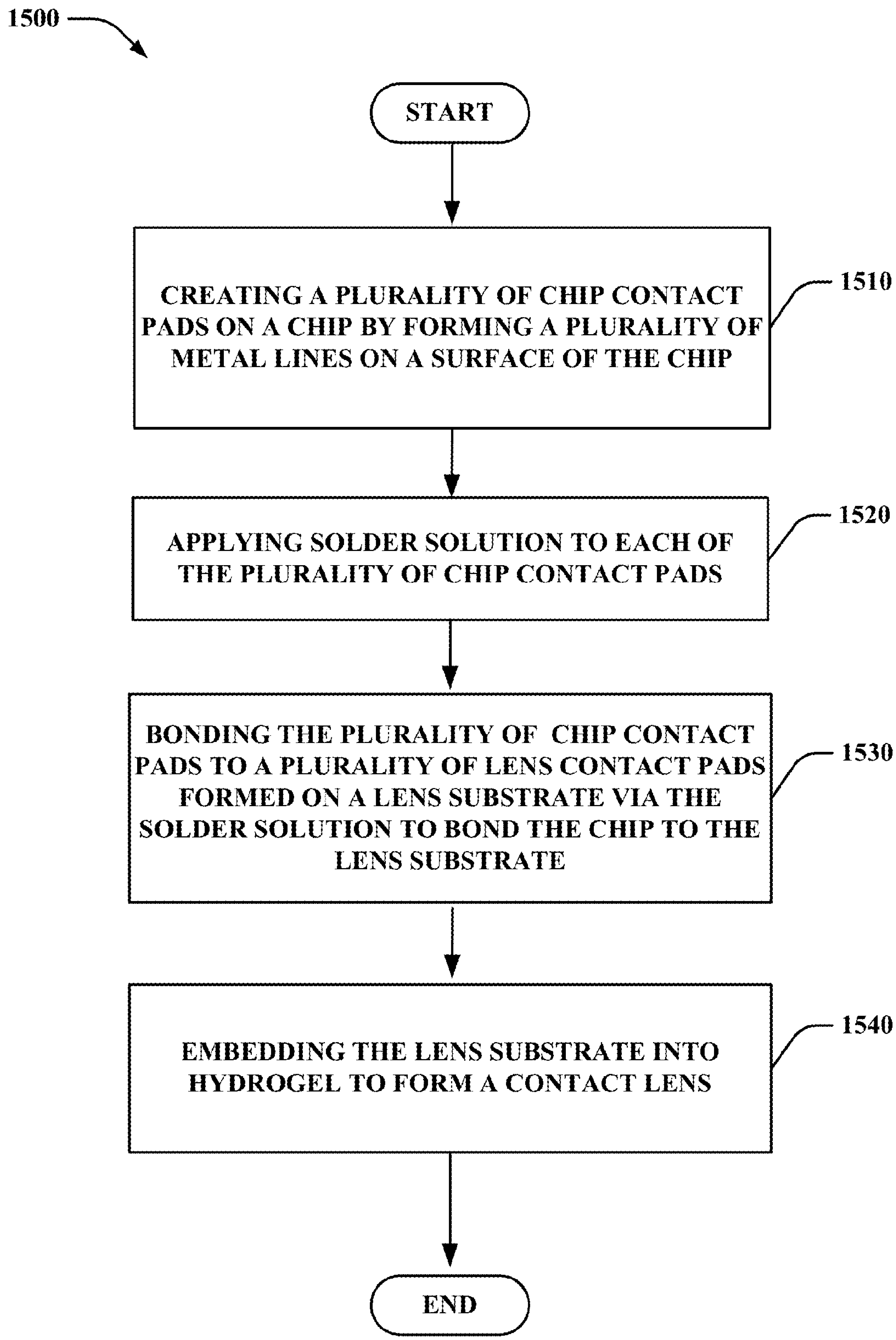
1500
START
CREATING A PLURALITY OF CHIP CONTACT PADS ON A CHIP BY FORMING A PLURALITY OF METAL LINES ON A SURFACE OF THE CHIP
1510
APPLYING SOLDER SOLUTION TO EACH OF THE PLURALITY OF CHIP CONTACT PADS
1520
BONDING THE PLURALITY OF CHIP CONTACT PADS TO A PLURALITY OF LENS CONTACT PADS FORMED ON A LENS SUBSTRATE VIA THE SOLDER SOLUTION TO BOND THE CHIP TO THE LENS SUBSTRATE
1530
EMBEDDING THE LENS SUBSTRATE INTO HYDROGEL TO FORM A CONTACT LENS
1540
END

FIG. 15

ASSEMBLING THIN SILICON CHIPS ON A CONTACT LENS

TECHNICAL FIELD

This disclosure generally relates to a contact lens having a thin silicon chip integrated therein and methods for assembling the silicon chip within the contact lens.

BACKGROUND

Silicon chips are generally assembled using flip chip bonding or wire bonding. Flip chip bonding is a method for interconnecting semiconductor devices to external circuitry (e.g., a circuit board or another chip or wafer), with solder bumps that have been deposited onto chip pads. The solder bumps are deposited on the chip pads on a top side of the wafer during a final wafer processing step. In order to mount the chip to external circuitry it is flipped over so that its top side faces down, and aligned so that its pads align with matching pads on an external circuit. The solder bumps are then melted to complete interconnects. In wire bonding, the chip is mounted to external circuitry in an upright position and wires are used to interconnect the chip pads to external circuitry. However, these silicon chip assembly methods are not suitable for assembling silicon chips on or within a contact lens. Furthermore, standard chips are too thick to fit onto a contact lens.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A and **1**B present alternative perspectives of an example contact lens having a silicon chip integrated therein/thereon in accordance with aspects described herein.

FIGS. **2**A-**2**C present cross-sectional views of example embodiments of a contact lens having a silicon chip integrated therein in accordance with aspects described herein.

FIG. **3** depicts a process for creating silicon chips that can be assembled onto a contact lens in accordance with aspects described herein.

FIG. **4** illustrates a high level overview of processes by which a silicon chip is assembled onto a contact lens substrate in accordance with aspects described herein.

FIGS. **5**A-**5**E illustrate an exemplary process **500** by which a silicon chip is assembled onto a contact lens substrate in accordance with aspects described herein.

FIGS. **6**A-**6**D illustrate another an alternative perspective of exemplary process **500** by which a silicon chip is assembled onto a contact lens substrate in accordance with aspects described herein.

FIGS. **7**A-**7**D illustrate another exemplary process **700** by which a silicon chip is assembled onto a contact lens substrate in accordance with aspects described herein.

FIGS. **8**A-**8**D illustrate another an alternative perspective of exemplary process **800** by which a silicon chip is assembled onto a contact lens substrate in accordance with aspects described herein.

FIGS. **9**A-**9**D illustrate another exemplary process **900** by which a silicon chip is assembled onto a contact lens substrate in accordance with aspects described herein.

FIGS. **10**A-**10**D illustrate another an alternative perspective of exemplary process **900** by which a silicon chip is assembled onto a contact lens substrate in accordance with aspects described herein.

FIGS. **11**A-**11**C illustrate a process for employing a contact lens substrate having a silicon chip bonded thereon to form a contact lens in accordance with aspects described herein.

FIG. **12**A presents an alternative, three-dimensional view of a contact lens form in accordance with aspects described herein.

FIG. **12**B depicts the final processing of a contact lens form to form a contact lens in accordance with aspects described herein.

FIG. **13** presents a exemplary methodology by which a silicon chip is assembled onto and/or within a contact lens in accordance with aspects described herein.

FIG. **14** presents another exemplary methodology by which a silicon chip is assembled onto and/or within a contact lens in accordance with aspects described herein.

FIG. **15** presents another exemplary methodology by which a silicon chip is assembled onto and/or within a contact lens in accordance with aspects described herein.

DETAILED DESCRIPTION

Various aspects are now described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a more thorough understanding of one or more aspects. It is evident, however, that such aspects can be practiced without these specific details. In other instances, structures and devices are shown in block diagram form in order to facilitate describing one or more aspects.

In one or more aspects, the disclosed subject matter relates to methods for manufacturing a contact lens having an integrated circuit integrated therein or thereon. In an aspect, the method involves creating a plurality of lens contact pads on a lens substrate and creating a plurality of chip contact pads on an integrated circuit element or chip, such as a silicon chip. Assembly bonding material is then applied to the plurality of lens contact pads or the plurality of chip contact pads. The chip is then bonded to the lens substrate via the assembly bonding material whereby the lens contact pads are aligned with the chip contact pads.

After the chip is bonded to the lens substrate, the lens substrate is formed into a contact lens. In an aspect, prior to forming the lens substrate into a contact lens, the chip is sealed onto the lens substrate. The lens substrate is then cut into a ring shape and molded to match curvature of an eye over which the contact lens is to be worn. The molded lens substrate is then embedded into a hydrogel to form the contact lens.

In some aspects, the plurality of chip contact pads are formed as metal lines on the chip using photolithography. Similarly, the plurality of lens contact pads can be formed as metal lines on the lens substrate using photolithography. Yet in other aspects, the plurality of lens contact pads are formed as a plurality of metal squares having a length of about 100 microns or less.

The subject methods enable assembly of thin silicon chips within a contact lens without use of bumped pads and standard chips. In some embodiments, the disclosed methods involve thinning a silicon ship substrate down to a thickness of less than about 100 microns (e.g., within the range of 20-100 microns thick) and then dicing the thinned substrate into chips smaller than 1 mm on each side. It is to be appreciated that these noted ranges/sizes are merely exemplary, and any suitable thickness or size can be employed in accordance with embodiments described herein. Metal lines are patterned onto a chip and/or a lens substrate to create contact pads for the chip and/or the lens substrate. The metal lines also serve as wires to connect other chips and/or other electrical components of the contact lens (e.g. antennas, sensors, light illuminating diodes (LEDS), and etc.).

In various embodiments, in order to assemble a chip to the lens substrate, a small amount of low temperature assembly bonding material is placed onto contact pads of either the lens substrate or the chip using a syringe. The contact pads of the chip are then aligned with the contact pads of the lens substrate and the chip is bonded to the lens substrate using the solder material. For example, the lens substrate can include multiple contact pads that can be segmented into multiple assembly sites for assembling a chip thereto. Once respective contact pads of a particular assembly site on the lens substrate are covered with solder material, the contact pads of the chip are aligned with the lens substrate contact pads in the assembly site and the chip is bonded to the assembly site using a flip-chip bonder. The flip-chip bonder tool aligns the chip contact pads with the lens substrate contact pads and applies pressure along with temperature to create a mechanical and electrical connection between the chip and the lens substrate.

After the chip is bonded to the lens substrate, the chip can be sealed onto the lens substrate with a substance (e.g. parylene) to make the lens substrate biocompatible and to hold the chip in place. The lens substrate can then be formed into a contact lens. For example, in an aspect, the lens substrate is cut into a ring shape. The ring shape can include indentations on the inner and/or outer edges of the ring to facilitate molding of the ring and to reduce wrinkling. The ring is then molded to match curvature of the eye. The ring is further embedded into hydrogel to complete the contact lens assembly process.

FIGS. **1**A and **1**B depict various perspectives of an example contact lens **100** having an integrated circuit or chip **102** integrated therein/thereon. As used herein, the terms integrated circuit and chip are used interchangeably. FIG. **1**A illustrates a three dimensional image of example contact lens **100**, and FIG. **1**B presents a cross-sectional view of example contact lens **100** being worn over an eye **104**. Contact lens **100**, and additional contact lenses disclosed herein are generally provided in a spherical shape that conforms to shape of an eye.

With reference to FIG. **1**B, contact lens **100** includes two primary surfaces, an inner surface **108** and an outer surface **106**, both of which are spherical. The inner surface **108** is concave and is adjacent to/rests on, a surface of the eye **104**. The outer surface **106** is convex and opposite the inner surface **108**. The contact lens **100** has a thickness that spans in a horizontal direction between inner surface **106** and outer surface **104**. Chip **102** is located within a thickness of the contact lens **102**. In general aspects, as illustrated in FIG. **1**B the width of the lens is thickest (relative to the width of the lens at other areas of the lens) at a center point of the lens, tapering outwardly to a knifelike edge at the perimeter of the lens. The particular dimensions (including dimensions attributable to thickness, diameter, curvature, and etc.) of the subject contact lenses are not critical and may vary.

As generally described herein, chip **102** is silicon chip that can be employed by contact lens **100** to facilitate electrical operations of the contact lens. In particular, chip **102** can perform various computing and logic functions of contact lens **102**. Further, although not shorn in the figures, it is to be appreciated that contact lenses disclosed herein can include multiple electrical components that connect to silicon chip **102**. For example, contact lenses disclosed herein can include sensors, antennas, LEDs, power sources, and etc. In addition, although contact lens **100** (and additional contact lenses described herein) is depicted having a single silicon chip **102**, it should be appreciated than contact lens **100** (and additional contact lenses described herein) can be provided having a plurality of chips **102** integrated therein.

In an embodiment, silicon chip **102** is a piece of almost pure silicon having a size smaller than standard silicon chips employed in standard computing devices. For example, while most computing devices employ silicon chips that are one square centimeter and have a thickness of about 1 millimeter, chip **102** can have a size of about 1 square millimeter and a thickness less than 100 microns. In an aspect, silicon chip **102** contains a plurality (up to millions) of transistors and other small electronic circuit components, packed and interconnected in layers beneath the surface of the chip. The surface of the silicon chip can further include a grid of metallic lines etched thereon which are used to make electrical connections to other components of the chip **102** and/or the contact lens **100**

FIGS. **2**A-**2**C present cross-sectional views of example embodiments of a contact lens having silicon chip **206** integrated therein in accordance with aspects described herein. The contact lenses depicted in FIGS. **2**A, **2**B, and **2**C, lenses **200**, **202**, and **204** respectively, respectively have two or more layers where silicon chip **206** is integrated within one of the layers. The lenses **200**, **202**, and **204** are formed by first integrating silicon chip **206** into a lens substrate layer **214** and then forming one or more additional contact lens layers **216** on and/or around the lens substrate layer **214**. In particular, as described in detail infra, chip **206** is first assembled onto a lens substrate **214**. In an aspect, the lens substrate is then molded into a lens shape to fit the contours of the eye **208** and combined within a contact lens material (e.g. hydrogel) to form the contact lens.

The lens substrate layer **214** having the silicon chip **206** and the contact lens material layer **216** can be combined in a variety of manners. In an aspect, in order to combine the lens substrate layer **214** and the contact lens material layer **216**, the lens substrate can be dipped into liquid contact lens material **216**. In another aspect, in order to combine the lens substrate layer **214** and the contact lens material layer **216**, the lens substrate **214** can be coated/covered with lens contact material **216** on one or both sides of the lens substrate. Still in other aspects, in order to combine the lens substrate layer **214** and the contact lens material layer **216**, the lens substrate **214** can be pressed into and/or bonded with one or more layers of lens contact material **216**.

The lens substrate layer **214** and the lens material layer(s) **216** can include various materials. In an aspect, the lens substrate layer **214** and the lens material layer **216** comprise the same material. In another aspect, the lens substrate layer **214** and the lens material layer comprise different materials. The lens substrate layer **214** can include any suitable material that enables fixation of contact pads to the material (e.g. metal pads and/or metal lines) and fixation of a chip **206** to the contact pads.

Some exemplary material that can be employed as the lens substrate layer material **214** include but are not limited to a soft polymer material including but not limited to, a hydrogel, a silicone based hydrogel, a polyacrlyamide, or a hydrophilic polymer. For example, in an aspect, contact lens substrate layer **214** is formed from a substrate material that includes at least one of a crosslinked hydrogel comprising hydrophilic monomers (e.g. N-Vinylpyrrolidone, 1-Ethenyl-2-pyrrolidone,N,N-dimethylacrylamide, 2-hydroxyethyl methacrylate, hydroxyethyl acrylate, methacrylic acid and acrylic acid), a strengthening agent, a ultraviolent light (UV) blocker, or a tint.

In another aspect, contact lens substrate layer **214** is formed from a substrate material that includes at least of a one silicone hydrogel (e.g. crosslinked hydrogels containing silicone macromers and monomers, as well as hydrophilic monomers that absorb water). In yet another aspect, contact lens substrate layer **214** is formed from a substrate material that includes one or more rigid materials including but not limited to, a silicone polymer, polymethyl methacrylate, or rigid gas permeable materials.

The lens material layer **216** can include any suitable material that provides support for the lens substrate layer **214**, contain/embed the lens substrate layer **214** and/or otherwise form a structural and/or functional body of the contact lens. Some exemplary materials that can be employed as the lens material layer **216** can include but are not limited to a soft polymer material including but not limited to, a hydrogel, a silicone based hydrogel, a polyacrlyamide, or a hydrophilic polymer. For example, in an aspect, lens material layer **216** is formed from a substrate material that includes at least one of a crosslinked hydrogel comprising hydrophilic monomers (e.g. N-Vinylpyrrolidone, 1-Ethenyl-2-pyrrolidone,N,N-dimethylacrylamide, 2-hydroxyethyl methacrylate, hydroxyethyl acrylate, methacrylic acid and acrylic acid), a strengthening agent, a ultraviolent light (UV) blocker, or a tint. In another aspect, lens material layer **216** is formed from a substrate material that includes at least of a one silicone hydrogel (e.g. crosslinked hydrogels containing silicone macromers and monomers, as well as hydrophilic monomers that absorb water). In yet another aspect, lens material layer **216** is formed from a substrate material that includes one or more rigid materials including but not limited to, a silicone polymer, polymethyl methacrylate, or rigid gas permeable materials.

As illustrated in FIG. 2A, in an aspect, the lens substrate layer **214** is located at an outer surface **210** of the contact lens **200** and the lens material layer **216** is located at an inner surface **212** of the contact lens **200**. According to this aspect, contact lens **200** can include two layers, lens substrate layer **214** and a lens material layer **216**. The lens substrate layer **214** includes the silicon chip and the silicon chip can further be located at/on the outer surface **210** of the contact lens. In an example, in order to form contact lens **200**, silicon chip **206** is first integrated onto lens substrate layer **214** and then the lens substrate layer **214** is coated on its concave side with contact lens material **216**.

As shown in FIG. 2B, in another aspect, the lens substrate layer **214** is located at an inner surface **212** of contact lens **202** and the lens material layer **216** is located at an outer surface **210** of the contact lens **202**. According to this aspect, contact lens **202** can also include two layers, lens substrate layer **214** and a lens material layer **216**. The lens substrate layer **214** includes the silicon chip **206** and the silicon chip can further be located at/on the inner surface **212** of the contact lens **202**. In an example, in order to form contact lens **202**, silicon chip **206** is first integrated onto lens substrate layer **214** and then the lens substrate layer **214** is coated on its convex side with contact lens material **216**.

As seen in FIG. 2C, in yet another aspect, contact lens **204** includes a lens substrate layer **214** located between two layers of lens material **216**. According to this aspect, contact lens **204** can also include three layers. The lens substrate layer **214** includes the silicon chip **206** and thus the silicon chip is located suspended between the inner surface **212** and the outer surface **210** of the contact lens **204**. In an example, in order to form contact lens **204**, silicon chip **206** is first integrated onto lens substrate layer **214** and then the lens substrate layer **214** is dipped into or otherwise entirely coated/embedded within, contact lens material **216**.

With reference now to FIG. **3**, illustrated is a process **300** for creating silicon chips that can be assembled onto a contact lens in accordance with aspects described herein. A silicon chip substrate **301** is first thinned down to a thickness of less than 100 microns. In an aspect, the silicon chip substrate **301** is thinned down to a thickness of less than 75 microns. In another aspect, the silicon chip substrate **301** is thinned down to a thickness of less than 50 microns. Still, in yet another aspect, the silicon chip substrate **301** is thinned down to a thickness of less than 35 microns. The thinned silicon chip substrate **302** is then diced into a plurality of silicon chips **304** having a size suitable for integration into a contact lens. In particular, the size and shape of the chip **304** is restricted by thickness and curvature of a contact lens in which it is to be integrated. A chip **304** can have a rectangular shape or a square shape. In an aspect, a chip **304** can have sides less than 15 mm. In another aspect, a chip **304** can have sides less than 10 mm. In another aspect, a chip **304** can have sides less than 5.0 mm. Still in yet another aspect, a chip **304** can have sides less than 1.0 mm.

FIGS. **4-10**D illustrate exemplary embodiments of processes by which a chip **304** is assembled onto a contact lens substrate **418** in accordance with aspects described herein. FIG. **4** illustrates a high level overview of processes by which a chip **304** is assembled onto a contact lens substrate **418** while FIGS. **5**A-**10**D illustrate detailed steps in various processes by which a chip **304** is assembled onto a contact lens substrate **418**. After one or more chips have been assembled onto contact lens substrate **418**, the contact lens substrate can be modified into a contact lens. In particular, the contact lens substrate **418** can be molded into the shape of a contact lens to become the contact lens substrate layer (e.g. layer **214**) in an assembled contact lens (e.g. lenses **200**, **202**, **204** and the like). In various aspects, the contact lens substrate **418** can include one or more of the structure and/or functionality of contact lens substrate layer **214** (and vice versa). In particular, it should be appreciated that contact lens substrate **418** can comprise the materials described with reference to contact lens substrate layer **214**.

Turning initially to FIG. **4**, a silicon chip **304** that has been sized to a suitable size for integration into a contact lens (e.g. having a thickness less than 100 microns and sides less than about 1 mm) is depicted having metal lines **402** provided thereon. In particular, after a silicon chip **304** is created via process **300**, prior to integration onto a contact lens substrate **418**, the silicon chip **304** can be processed to form various functional features of the silicon chip, including at least chip contact pads. Chip contact pads provide the contact point for electrically connecting a chip **304** to substrate **418** and/or other electrical component. In an aspect, traditional metal chip contact pads (not depicted) can be created on a surface of chip **304**. For example, metal chip pads in the form of small and thin sheets of metal in the shape of squares or rectangles can be formed on a surface of the chip **304** to create the chip contact pads. Such metal contact pads can have sides less than 100 microns.

However, in another aspect, as depicted in FIG. **4**, metals lines **402** are patterned onto a surface of chip **304**. For example, metal lines **402** can be patterned onto a surface **406** of a chip **304** using photolithography. These metal lines **402** serve as chip contact pads for the chip **304** and also serve as wires to connect the chip **304** to other chips and/or components of a contact lens (e.g. antennas, sensors, LEDs, and etc.) in which the chip **304** is integrated. For example, intersection points **404** of metal lines **402** can serve as the chip contact pads of chip **304**. However, it should be appreciated that any point of a metal line **402** can serve as a chip contact pad. In addition, although intersecting parallel metal lines **402** are shown forming a grid pattern on chip **304**, such a line configuration is merely depicted for exemplary purposes. In particular, lines **402** can be formed in any pattern, in includes patterns having non-intersecting lines and patterns having non-parallel lines.

In an aspect, the surface of chip **304** on which the metal lines are formed, surface **406**, is a substantially flat polymer layer provided on the chip **304**. According to this aspect, the metal lines **402** are patterned onto the substantially flat polymer layer using photolithography. For example, the polymer layer can include but is not limited to parylene, polyimide, and polyethylene terephthalate (PET).

Contact lens substrate **418** is also presented having lens contact pads located on a surface thereof. In an aspect, lens contact pads provide the contact points for electrically and/or physically connecting the substrate **418** with the chip **304** and/or electrically connecting other electrical components provided within a contact lens in which the lens substrate **418** is integrated, to the chip **304**. In an aspect, traditional metal chip contact pads **414** can be created on a surface of lens substrate **418**. For example, metal chip pads in the form of small and thin sheets of metal in the shape of squares or rectangles can be formed on a surface of the lens substrate **418** to create the lens contact pads. Such metal contact pads can have sides less than 100 microns.

However, in another aspect, metals lines **416** are patterned onto a surface of contact lens substrate **418** in a same or similar fashion as metal lines **402** patterned on chip **304**. For example, metal lines **416** can be patterned onto a surface of lens substrate **418** using photolithography. As with metal lines **402**, metal lines **416** can serve as lens contact pads for the lens substrate **418** and also serve as wires to connect the chip **304** to other chips and/or components of a contact lens (e.g. antennas, sensors, LEDs, and etc.) in which the chip **304** is integrated. In addition, although intersecting parallel metal lines **416** are shown forming a grid pattern on substrate **418** such a line configuration is merely depicted for exemplary purposes. In particular, lines **416** can be formed in any pattern, in includes patterns having non-intersecting lines and patterns having non-parallel lines.

In an aspect, the lens substrate and/or a surface of lens substrate **418** on which the metal lines **416** are formed is a substantially flat polymer layer. According to this aspect, the metal lines **416** are patterned onto the substantially flat polymer layer using photolithography. For example, the polymer layer can include but is not limited to parylene, polyimide, and polyethylene terephthalate (PET).

It should be appreciated that both traditional metal contact pads **414** and metal line contact pads **416** are provided on lens substrate **418** merely for exemplary purposes. Further, although only a partial area of the lens substrate **418** is presented having contact pads thereon, it should be appreciated that any portion of the substrate **418** can be provided with contact pads. For example, the entire surface of the substrate **418** can be patterned with metal lines or square metal pads. According to this example, a subset of the metal lines/metal pads can be selectively employed as the contact pads for assembly of a chip thereon. In other words, a subset of the metal lines/metal pads can be selectively employed as an assembly site for assembly of a chip thereon and the substrate can be provided with a plurality of potential assembly sites. As used herein, the term assembly site refers to an area of substrate **418** having lens contact pads that can be aligned with the contact pads of a chip.

In order to attach silicon chip **304** to contact lens substrate **418**, an assembly bonding material (not shown) is applied to either the chip or the lens substrate **418**. In an aspect, the assembly bonding material includes an anisotropic conductive film (ACF) or an anisotropic conductive paste (ACP). ACF and ACP are materials that establish a conducting path when pressed between two metal pads, such as a lens contact pad and a chip contact pad. According to this aspect, an ACF or ACP is applied over an entire assembly site on the substrate **418** (and/or the chip) having lens (or chip) contact pads therein so as to cover the contact pads and the area between and around the contact pads. With this aspect, assembly bonding material does not need to be applied to the contact pads individually.

After application of the ACF or ACP, the silicon chip **304** is then flipped over, following arrow **408**, so that the surface **406** of the silicon chip **304** having the chip contact pads (e.g. the surface having the metal lines **402**) faces a surface of the contact lens substrate **418** having the lens contact pads thereon. Dashed lines **402** presented on flipped chip **304** are indicative of the metal lines **402** now on the underside **306** of the chip. The chip **304** is then lowered onto the substrate **418** and the chip contact pads are aligned with the lens contact pads. The chip **304** is then assembled onto the lens substrate via pressing the chip **304** onto the ACF or ACP and heating the chip **304**/substrate **418** assembly to cure or solidify the chip **304** connection with the substrate **418**. In particular, the ACP or ACF is activated in order to secure chip **304** to substrate **418** in part by the heating. For example, activation of an ACP or ACF can include boiling a flux out of the ACP or ACF to create a conductive path between the chip contact pads and lens contact pads and to create an adhesive (e.g. an underfill) material that bonds chip **304** to substrate **418**. In an aspect, heating of the of the chip **304**/substrate **418** assembly is performed so that conduction results in a single direction so that the contact pads do not short.

In another aspect, the assembly bonding material includes a solder solution or solder paste. According to this aspect, solder solution or solder paste (not shown) is applied to either the chip contact pads or the lens contact pads in a particular assembly site. In an aspect, the solder solution/paste is applied to respective ones of either the chip contact pads or the lens contact pads using a syringe. The silicon chip **304** is then flipped over, following arrow **408**, so that the surface **406** of the silicon chip **304** having the chip contact pads (e.g. the surface having the metal lines **402**) faces a surface of the contact lens substrate **418** having the lens contact pads thereon. Dashed lines **402** presented on flipped chip **304** are indicative of the metal lines **402** now on the underside **306** of the chip. The chip **304** is then lowered onto the substrate **418** and the chip contact pads are aligned with the lens contact pads. Head and pressure are then applied to at least one of the chip **304** or the lens substrate **418** so that the solder solution is flowed and solidified so as to bond the chip **304** to the lens substrate **418**. Arrow **410** shows an example where the chip **304** is bonded to an assembly site on the substrate **418** that comprises metal squares as contact pads. Arrow **412** shows an example where the chip **304** is bonded to an assembly site on the substrate **418** that comprises metal lines as contact pads.

In some aspects, an underfill is applied to the lens substrate/chip complex in order to hold the chip **304** onto the substrate **418**. In particular, connections established between the chip **304** and the substrate **418** can be relatively weak when using a solder solution/paste as the assembly bonding material. Accordingly, an underfill material can be applied between the chip **304** and the substrate so as to flow around the respective solder pads and solidified solder material to further facilitate bonding of the chip **304** to the substrate. The underfill can include a non-conductive or substantially non-conductive material such as an epoxy or adhesive.

In an aspect, flipping **408**, alignment of chip **304** with contact pads on lens substrate **418**, and bonding is performed using a flip chip bonder. As used herein, the term flip chip bonder refers to a tool that performs functions and features of traditional flip chip bonding methods, including at least flipping of chip **304**, alignment of chip **304** with substrate **418**, and application of heat and pressure to chip **304** and substrate **418** such that the chip **304** and the substrate **418** bond via the solder solution provided there between.

In an aspect, the assembly bonding material that is applied to the lens substrate or chip is a low activation temperature material. For example, in some aspects, the assembly bonding material includes an ACF or an ACP that has a low activation temperature, such as below 200° C. In other aspects, the assembly bonding material includes a solder material that has a low melting point, such as below 200° C. In another aspect, the assembly bonding material can have an activation temperature or boiling point less than 150° C. In another aspect, the assembly bonding material can have an activation temperature or boiling point less than 100° C. In yet another aspect, the assembly bonding material can have an activation temperature or boiling point less less than 85° C. Still in yet another aspect, the assembly bonding material can have an activation temperature or boiling point less than 65° C.

Some exemplary low temperature solder solutions/pastes that can be employed as the assembly bonding material can include but are not limited to solutions or pastes having varying ratios of indium, tin, and/or bismuth. For example, indium alloy number 19 from Indium Corp. can be employed as an exemplary solder solution and has a ration of 51% In, 32.5% Bi, and 16.5 Sn with a melting temperature of about 60° C. In an aspect, an employed solder solution/paste is lead-free so as not to disrupt an eye in which a contact lens, having a chip **304** integrated therein, is worn. In some aspects, the solder solution can also be mixed with a flux or acidic solution (such as HCL and water) to prevent or reduce oxidation of the solder solution. Some exemplary fluxes can include but are not limited to TACFlux® 020B and Indalloy Flux #4-OA from Indium Corp. Additionally, a commercially available solder solution can be employed as the assembly bonding material that is formed as a paste suspended in a solder solution, such NC-SMQ®90 Solder Paste from Indium Corp.

Looking now to FIGS. **5A-5E**, illustrated is an exemplary process **500** by which a silicon chip is assembled onto a contact lens substrate **418** in accordance with aspects described herein. In FIGS. **5A-5E**, it should be appreciated that only a portion of contact lens substrate **418** is presented for exemplary purposes. Process **500** follows in part, arrow **410** of FIG. **4**. In particular, process **500** present an embodiment where chip **304** is bonded to an assembly site on the substrate **418** that comprises metal squares **414** as contact pads.

As seen in FIG. **5A**, a contact lens substrate **418** is provided having a plurality of metal square contact pads **414** created thereon. A chip **304** is assembled to substrate **418** using either solder solution according to FIG. **5B** or a solder film or paste including ACF or ACP respectively according to FIG. **5C**. Accordingly, process **500** can proceed with steps according to FIG. **5B** or according to FIG. **5C**.

In FIG. **5B**, solder solution **502** is applied to each of the lens contact pads **414**. (The solder solution **502** is represented by the darkening of the lens contact pads **414** as compared to the lens contact pads **414** of FIG. **5A**). In an aspect, the solder solution **502** is selectively applied to each of the lens contact pads **414** using a syringe, pipette, needle, or other precise applicator tool. Then a chip **304** having chip contact pads in the form of metal lines **402** is flipped over and aligned with lens substrate **418**. In particular, the chip contact pads, (such as the intersection points of the metal lines **402**), are aligned with each of the lens contact pads **414** having solder solution **502** thereon.

In FIG. **5C**, (the alternative to FIG. **5B**), an ACF or ACP **506** is applied to the lens substrate **418** so as to cover the lens contact pads **414** and the area around the respective lens contact pads **414** in the assembly site. Then a chip **304** having chip contact pads in the form of metal lines **402** is flipped over and aligned with lens substrate **418**. In particular, the chip contact pads, (such as the intersection points of the metal lines **402**), are aligned with each of the lens contact pads **414** having an ACF or ACP thereon.

In FIG. **5D**, the chip **304** is lowered onto the lens substrate **418** and the chip is bonded to the lens substrate via the solder solution or the ACF/ACP in response to the application of pressure and/or heat. For example, a flip chip bonder can perform the flipping, aligning and bonding aspects of method **500**. In an aspect, heat is applied at a temperature less than 200° C. to substantially only the area of the substrate **418** where the chip **304** is being assembled (e.g. the assembly sites) so as to cause no or limited damage to the remaining area of the substrate. In FIG. **5E**, once the solder solution or ACF/ACP has been solidified, hardened and/or cured, in an aspect, the chip **304** can be sealed onto the lens substrate **418** using a sealant **504**. The sealant **504** can cover and/or otherwise coat the chip **304** to hold the chip **304** in place on the lens substrate **418** and/or to make the lens substrate/chip complex biocompatible. In an aspect, (not shown), the entire substrate/chip complex can be coated in a sealant **504**. For example, the entire substrate/chip complex can be dipped or rinsed with a sealant **504**. In an aspect, the sealant **504** is parylene or polyimide.

FIGS. **6A-6D**, illustrate an alternative perspective of exemplary process **500** by which a silicon chip is assembled onto a contact lens substrate **418** in accordance with aspects described herein. In particular, FIGS. **6A-6D** present cross-sectional views of chip **304** and lens **418** during process **500**.

As seen in FIG. **6A**, a contact lens substrate **418** is provided having a plurality of metal square contact pads **414** created thereon. In FIG. **5B**, solder solution **502** is applied to each of the lens contact pads **414**. In an aspect, the solder solution **502** is selectively applied to each of the lens contact pads **414** using a syringe, pipette, needle, or other precise applicator tool. Then a chip **304** having chip contact pads **402** is aligned with lens substrate **418**. In particular, the chip contact pads **402** are aligned with each of the lens contact pads **414** having solder solution **502** thereon. In an aspect, the chip contact pads **402** are the intersection points **404** of the metal lines **402** as presented on chip **304** in FIG. **4**.

In FIG. **6C**, the chip **304** is lowered onto the lens substrate **418** and the chip is bonded to the lens substrate via the solder solution in response to the application of pressure and/or heat. In an aspect, heat is applied at a temperature less than 200° C. to substantially only the area of the substrate **418** where the chip **304** is being assembled (e.g. the assembly sites) so as to cause limited damage to the remaining area of the substrate. For example, a flip chip bonder can perform the flipping, aligning and bonding aspects of method **500**. In an aspect, an underfill material (not shown) can be applied between the lens substrate **418** and the chip **304** so as to fill in gaps between the solidified solder material and further adhere the chip **304** to the substrate **418**. In FIG. **6D**, once the solder solution has been solidified, hardened and/or cured, in an aspect, the chip **304** can be sealed onto the lens substrate **418** using a sealant

504. The sealant **504** can cover and/or otherwise coat the chip **304** to hold the chip **304** in place on the lens substrate **418** and/or to make the lens substrate/chip complex biocompatible. In an aspect, (not shown), the entire substrate/chip complex can be coated in a sealant **504**. For example, the entire substrate/chip complex can be dipped or rinsed with a sealant **504**.

Looking now to FIGS. **7A-7D**, illustrated is another exemplary process **700** by which a silicon chip is assembled onto a contact lens substrate **418** in accordance with aspects described herein. In FIGS. **7A-7D**, it should be appreciated that only a portion of contact lens substrate **418** is presented for exemplary purposes. Process **700** follows in part, arrow **412** of FIG. **4**. In particular, process **700** present an embodiment where chip **304** is bonded to an assembly site on the substrate **418** that comprises metal lines **416** as contact pads.

As seen in FIG. **7A**, a contact lens substrate **418** is provided having a plurality of metal lines **416** created thereon. The metal lines **416** serve as the lens contact pads. In an aspect, the intersection point of the metal lines in particular serve as the lens contact pads. According to this aspect, solder solution **502** is applied to the lens contact pads **416** at each metal line intersection point. In an aspect, the solder solution **502** is selectively applied to each of the lens contact pads **416** using a syringe, pipette, needle, or other precise applicator tool. In FIG. **7B**, a chip **304** having chip contact pads in the form of metal lines **402** is flipped over and aligned with lens substrate **418**. In particular, the chip contact pads, (such as the intersection points of the metal lines **402**), are aligned with each of the lens contact pads **416**, the metal line **416** intersection points, having solder solution **502** thereon.

In FIG. **7C**, the chip **304** is lowered onto the lens substrate **418** and the chip is bonded to the lens substrate via the solder solution in response to the application of pressure and/or heat. In an aspect, heat is applied at a temperature less than 200° C. to substantially only the area of the substrate **418** where the chip **304** is being assembled (e.g. the assembly sites) so as to cause no or limited damage to the remaining area of the substrate. For example, a flip chip bonder can perform the flipping, aligning and bonding aspects of method **700**. In an aspect, an underfill material (not shown) can be applied between the lens substrate **418** and the chip **304** so as to fill in gaps between the solidified solder material and further adhere the chip **304** to the substrate **418**. In FIG. **7D**, once the solder solution has been solidified, hardened and/or cured, in an aspect, the chip **304** can be sealed onto the lens substrate **418** using a sealant **504**. The sealant **504** can cover and/or otherwise coat the chip **304** to hold the chip **304** in place on the lens substrate **418** and/or to make the lens substrate/chip complex biocompatible. In an aspect, (not shown), the entire substrate/chip complex can be coated in a sealant **504**. For example, the entire substrate/chip complex can be dipped or rinsed with a sealant **504**.

FIGS. **8A-8D**, illustrate an alternative perspective of exemplary process **700** by which a silicon chip is assembled onto a contact lens substrate **418** in accordance with aspects described herein. In particular, FIGS. **8A-8D** present cross-sectional views of chip **304** and lens **418** during process **700**.

As seen in FIG. **8A**, a contact lens substrate **418** is provided having a plurality of contact pads **416** created thereon. The contact pads **416** are formed from metal lines such as metal lines **416** that have been patterned onto the lens substrate **418** via photolithography. In an aspect, the contact pads **416** include intersection points of metal lines **416** as depicted in FIG. **4**. The contact pads **416** further have solder solution **502** applied thereto. In an aspect, the solder solution **502** is selectively applied to each of the lens contact pads **416** using a syringe, pipette, needle, or other precise applicator tool. In FIG. **8A**, a chip **304** having chip contact pads **402** is aligned with lens substrate **418**. In particular, the chip contact pads **402** are aligned with each of the lens contact pads **416** having solder solution **502** thereon. In an aspect, the chip contact pads **402** are similarly intersection points **404** of the metal lines **402** as presented on chip **304** in FIG. **4**.

In FIG. **8C**, the chip **304** is lowered onto the lens substrate **418** and the chip is bonded to the lens substrate via the solder solution in response to the application of pressure and/or heat. In an aspect, heat is applied at a temperature less than 200° C. to substantially only the area of the substrate **418** where the chip **304** is being assembled (e.g. the assembly sites) so as to cause no or limited damage to the remaining area of the substrate. For example, a flip chip bonder can perform the flipping, aligning and bonding aspects of method **700**. In an aspect, an underfill material (not shown) can be applied between the lens substrate **418** and the chip **304** so as to fill in gaps between the solidified solder material and further adhere the chip **304** to the substrate **418**. In FIG. **8D**, once the solder solution has been solidified, hardened and/or cured, in an aspect, the chip **304** can be sealed onto the lens substrate **418** using a sealant **504**. The sealant **504** can cover and/or otherwise coat the chip **304** to hold the chip **304** in place on the lens substrate **418** and/or to make the lens substrate/chip complex biocompatible. In an aspect, (not shown), the entire substrate/chip complex can be coated in a sealant **504**. For example, the entire substrate/chip complex can be dipped or rinsed with a sealant **504**.

Looking now to FIGS. **9A-9D**, illustrated is another exemplary process **900** by which a silicon chip is assembled onto a contact lens substrate **418** in accordance with aspects described herein. In FIGS. **9A-9B**, it should be appreciated that only a portion of contact lens substrate **418** is presented for exemplary purposes. Process **900** presents an embodiment where chip **304** is bonded to an assembly site on the substrate **418** that comprises metal square **414** as contact pads and where the bonding solution is applied to the chip contact pads.

As seen in FIG. **9A**, a silicon chip **304** is provided having a plurality of metal lines **402** created thereon. The metal lines **402** serve as the chip contact pads. In an aspect, the intersection points of the metal lines in particular serve as the chip contact pads. According to this aspect, solder solution **502** is applied to the chip contact pads **402** at each metal line intersection point. In an aspect, the solder solution **502** is selectively applied to each of the chip contact pads **402** using a syringe, pipette, needle, or other precise applicator tool. The chip is **304** is further flipped over following arrow **408** so that the chip contact pads having the solder solution applied thereto can face a surface of the lens substrate **418** having contact pads **414** thereon. The dashed lines on flipped chip **304** are indicative of the chip contact pads now on the underside **406** of the chip.

In FIG. **9B**, the flipped chip **304** having the chip contact pads with solder applied is aligned with lens substrate **418**. In particular, the chip contact pads, (such as the intersection points of the metal lines **402**), are aligned with each of the lens contact pads **414**. Lens substrate **418** is provided having contact pads **414** located thereon. Although lens contact pads **414** are presented as metal squares, it should be appreciated that the lens contact pads can be in the form of metal lines.

In FIG. **9C**, the chip **304** is lowered onto the lens substrate **418** and the chip is bonded to the lens substrate via the solder solution in response to the application of pressure and/or heat. In an aspect, heat is applied at a temperature less than 200° C. to substantially only the area of the substrate **418** where the chip **304** is being assembled (e.g. the assembly sites) so as to cause no or limited damage to the remaining area of the substrate. For example, a flip chip bonder can perform the flipping, aligning and bonding aspects of method **900**. In an aspect, an underfill material (not shown) can be applied between the lens substrate **418** and the chip **304** so as to fill in gaps between the solidified solder material and further adhere the chip **304** to the substrate **418**. In FIG. 9D, once the solder solution has been solidified, hardened and/or cured, in an aspect, the chip **304** can be sealed onto the lens substrate **418** using a sealant **504**. The sealant **504** can cover and/or otherwise coat the chip **304** to hold the chip **304** in place on the lens substrate **418** and/or to make the lens substrate/chip complex biocompatible. In an aspect, (not shown), the entire substrate/chip complex can be coated in a sealant **504**. For example, the entire substrate/chip complex can be dipped or rinsed with a sealant **504**.

FIGS. **10**A-**10**D, illustrate an alternative perspective of exemplary process **900** by which a silicon chip is assembled onto a contact lens substrate **418** in accordance with aspects described herein. In particular, FIGS. **10**A-**10**D present cross-sectional views of chip **304** and lens **418** during process **900**.

As seen in FIG. **10**A, a silicon chip **304** is provided having a plurality of metal lines **402** created thereon. The metal lines **402** serve as the chip contact pads. In an aspect, the contact pads **402** are the intersection points of the metal lines **402** (point **404**) as presented in FIG. **4**. According to this aspect, solder solution **502** is applied to the chip contact pads **402** at each metal line intersection point. In an aspect, the solder solution **502** is selectively applied to each of the chip contact pads **402** using a syringe, pipette, needle, or other precise applicator tool. The chip is **304** is further flipped over following arrow **408** so that the chip contact pads having the solder solution applied thereto can face a surface of the lens substrate **418** having contact pads **414** thereon.

In FIG. **10**B, the flipped chip **304** having the chip contact pads with solder applied is aligned with lens substrate **418**. In particular, the chip contact pads, (such as the intersection points of the metal lines **402**), are aligned with each of the lens contact pads **414**. Lens substrate **418** is provided having contact pads **414** located thereon. Although lens contact pads **414** are presented as metal squares, it should be appreciated that the lens contact pads can be in the form of metal lines.

In FIG. **10**C, the chip **304** is lowered onto the lens substrate **418** and the chip is bonded to the lens substrate via the solder solution in response to the application of pressure and/or heat. In an aspect, heat is applied at a temperature less than 200° C. to substantially only the area of the substrate **418** where the chip **304** is being assembled (e.g. the assembly sites) so as to cause no or limited damage to the remaining area of the substrate. For example, a flip chip bonder can perform the flipping, aligning and bonding aspects of method **900**. In an aspect, an underfill material (not shown) can be applied between the lens substrate **418** and the chip **304** so as to fill in gaps between the solidified solder material and further adhere the chip **304** to the substrate **418**. In FIG. **10**D, once the solder solution has been solidified, hardened and/or cured, in an aspect, the chip **304** can be sealed onto the lens substrate **418** using a sealant **504**. The sealant **504** can cover and/or otherwise coat the chip **304** to hold the chip **304** in place on the lens substrate **418** and/or to make the lens substrate/chip complex biocompatible. In an aspect, (not shown), the entire substrate/chip complex can be coated in a sealant **504**. For example, the entire substrate/chip complex can be dipped or rinsed with a sealant **504**.

Referring now to FIGS. **11**A-**11**C, illustrated is a process for employing a contact lens substrate having a silicon chip bonded thereon to form a contact lens in accordance with aspects described herein. As seen in FIG. **11**A, a contact lens substrate **1102** having a silicon chip **1104** bonded thereon is provided. In various aspects, the contact lens substrate **1102** and chip **1104** can include one or more of the structure and/or functionality of contact lens substrate layer **214** and chip **206**, and/or the contact lens substrate **418** and chip **304** (and vice versa). In an aspect, the chip **1104** is sealed to the contact lens substrate **1102** via a sealant (e.g. parylene).

The contact lens substrate **1102** is used to form a contact lens form **1112**. In an aspect, the contact lens substrate **1102** is molded into a shape of a contact lens form **1112**. (e.g. a round and curved shape). In particular, the contact lens substrate **1102** is molded to match the curvature of an eye in which the contact lens is to be worn. In some aspects, in order to facilitate molding the contact lens substrate **1102**, the contact lens substrate **1102** is cut into a shape that can be formed into the shape of a contact lens. For example, as seen in FIG. **11**B, the contact lens substrate **1102** can be cut into a circular shape or ring shape **1110**. The cut substrate **1110** shown in FIG. **11**B is cut out of the contact lens substrate **1102** along dotted line pattern **1106**. The cut substrate **1110** can include cut slits or incisions **1108** on inner and/or outer edges of the ring to facilitate forming the cut substrate **1110** into a contact lens shape. The cut substrate **1110** is cut out of the contact lens substrate **1102** so as to include the attached chip **1104**.

FIG. **11**C shows a two-dimensional view of a contact lens form **1112** formed out of contact lens substrate **1102**. Contact lens form **1112** includes chip **1104**. In an aspect, contact lens form **1112** is formed by closing off the incisions **1108** of cut substrate **1110**. For example, the open edges of cut substrate **1110** can be bended and brought together (e.g. following the dashed arrow of FIG. **11**B) to form the contact lens form **1112** of FIG. **11**C.

FIG. **12**A presents an alternative, three-dimensional view of contact lens form **1112**. In an aspect, contact lens form **1112** can be employed as a finished, wearable/functional contact lens. Contact lens form matches the shape of a contact lens and forms to the curvature of the eye in which it is to be worn. Contact lens form further includes the chip **1104** integrated thereon. However, in another aspect, contact lens form is further processed to form a finished, wearable/functional contact lens.

FIG. **12**B depicts the final processing of contact lens form **1112** to form a contact lens **1202**. Contact lens **1202** comprises the contact lens **1112** form embedded and/or coated on one or more sides with contact lens material **1204**. In various aspects, the contact lens material **1204** can include one or more of the structure and/or functionality of lens material **216** (and vice versa). For example, in an aspect, the contact lens material **1204** is hydrogel, such as silicone hydrogel. Contact lens **1202** can also include one or more of the structure and/or functionality contact lenses **100**, **200**, **202**, **204** (and vice versa). For example, contact lens **1202** can include contact lens form **1112** entirely embedded in contact lens material **1204** and/or partially covered with contact lens material **1204**. In an aspect, in order to form contact lens **1202**, contact lens form **1102** is dipped into a liquid contact lens material and then the contact lens material is allowed to solidify.

FIGS. **13**-**15** illustrates methodologies or flow diagrams in accordance with certain aspects of this disclosure. While, for purposes of simplicity of explanation, the methodologies are shown and described as a series of acts, the disclosed subject matter is not limited by the order of acts, as some acts may occur in different orders and/or concurrently with other acts from that shown and described herein. For example, those skilled in the art will understand and appreciate that a methodology can alternatively be represented as a series of interrelated states or events, such as in a state diagram. Moreover, not all illustrated acts may be required to implement a methodology in accordance with the disclosed subject matter. Additionally, it is to be appreciated that the methodologies disclosed in this disclosure are capable of being stored on an article of manufacture to facilitate transporting and transferring such methodologies to computers or other computing devices.

Referring now to FIG. **13**, presented is a flow diagram of an example application of systems and apparatuses disclosed in this description in accordance with an embodiment. In an aspect, in exemplary methodology **1300**, a contact lens is formed having a silicon chip integrated therein. At **1310**, a plurality of chip contact pads are formed on a chip by forming a plurality of metal lines on a surface of the chip. (e.g. using photolithography). At **1320**, solder solution is applied to each of a plurality of lens contact pads formed on a lens substrate (e.g. using a syringe). At **1330**, the plurality of chip contact pads are bonded to the plurality of lens contact pads via the solder solution to bond the chip to the lens substrate (e.g. using a flip chip bonder). Then at **1340**, the lens substrate is embedded into a hydrogel to form a contact lens.

Referring now to FIG. **14**, presented is a flow diagram of another example application of systems and apparatuses disclosed in this description in accordance with an embodiment. In an aspect, in exemplary methodology **1400**, a contact lens is formed having a silicon chip integrated therein. At **1410**, a plurality of chip contact pads are formed on a chip by forming a plurality of metal lines on a surface of the chip. (e.g. using photolithography). At **1420**, solder solution is applied to each of a plurality of lens contact pads formed on a lens substrate (e.g. using a syringe). At **1430**, the plurality of chip contact pads are bonded to the plurality of lens contact pads via the solder solution to bond the chip to the lens substrate (e.g. using a flip chip bonder). At **1450**, the lens substrate is sealed onto the chip (e.g. using a sealant **1504**). At **1460**, the lens substrate is cut into a ring shape and molded to match the curvature of an eye over which a contact lens is to be worn. Then at **1340**, the lens substrate is embedded into a hydrogel to form the contact lens.

Referring now to FIG. **15**, presented is a flow diagram of an example application of systems and apparatuses disclosed in this description in accordance with an embodiment. In an aspect, in exemplary methodology **1500**, a contact lens is formed having a silicon chip integrated therein. At **1510**, a plurality of chip contact pads are formed on a chip by forming a plurality of metal lines on a surface of the chip. (e.g. using photolithography). At **1520**, solder solution is applied to each of the plurality of chip contact pads (e.g. using a syringe). At **1530**, the plurality of chip contact pads are bonded to a plurality of lens contact pads via the solder solution to bond the chip to the lens substrate (e.g. using a flip chip bonder). Then at **1540**, the lens substrate is embedded into a hydrogel to form a contact lens.

What is claimed is:

1. A method for manufacturing a contact lens having an integrated circuit, comprising:
- creating a plurality of chip contact pads on a chip by forming a grid of metal lines on a surface of the chip, wherein the chip contact pads correspond to intersection points of the metal lines in the grid;
- applying assembly bonding material to each of a plurality of lens contact pads formed on a lens substrate, wherein the assembly bonding material includes an anisotropic conductive material;
- bonding the plurality of chip contact pads to the plurality of lens contact pads via the assembly bonding material to bond the chip to the lens substrate; and
- embedding the lens substrate and the chip bonded thereon into a contact lens material to form the contact lens.

2. The method of claim **1**, wherein the forming the grid of metal lines comprises forming the grid of metal lines using photolithography.

3. The method of claim **1**, further comprising, prior to the embedding, sealing the chip on the lens substrate.

4. The method of claim **1**, further comprising, prior to the embedding, cutting the lens substrate into a ring shape and molding the lens substrate to match a curvature of an eye over which the contact lens is to be worn.

5. The method of claim **1**, wherein the chip has a thickness of about 100 microns or less and a length of about 1.0 millimeter or less.

6. The method of claim **1**, wherein the contact lens material includes at least one of a hydrogel, a silicone hydrogel or a silicone elastomer.

7. The method of claim **1**, wherein the bonding is performed employing a flip-chip bonder.

8. A contact lens having an integrated circuit disposed thereon or therein formed by a process comprising the steps of:
- creating a plurality of chip contact pads on a chip by forming a grid of metal lines on a surface of the chip, wherein the chip contact pads correspond to intersection points of the metal lines in the grid;
- applying assembly bonding material to each of the plurality of chip contact pads, wherein the assembly bonding material includes an anisotropic conductive material;
- bonding the plurality of the chip contact pads to a plurality of lens contact pads formed on a lens substrate via the assembly bonding material to bond the chip to the lens substrate; and
- embedding the lens substrate having the chip bonded thereon into a contact lens material to form the contact lens.

9. The contact lens of claim **8**, wherein the step of forming the grid of metal lines comprises forming the grid of metal lines using photolithography.

10. The contact lens of claim **8**, wherein the process further comprises the step of, prior to the embedding, sealing the chip on the lens substrate.

11. The contact lens of claim **8**, wherein the process further comprises the step of, prior to the embedding, cutting the lens substrate into a ring shape and molding the lens substrate to match a curvature of an eye over which the contact lens is to be worn.

12. The contact lens of claim **8**, wherein the chip has a thickness of about 100 microns or less and a length of about 1.0 millimeter or less.

13. The contact lens of claim **8**, wherein the bonding is performed employing a flip-chip bonder.

14. The contact lens of claim **8**, wherein the contact lens material includes at least one of a hydrogel, a silicone hydrogel or a silicone elastomer.

15. A method for manufacturing a contact lens having an integrated circuit, comprising:
- creating a plurality of lens contact pads on a lens substrate;
- creating a plurality of chip contact pads on a chip, wherein the plurality of chip contact pads corresponding to intersection points of a grid of metal lines on the chip;
- applying assembly bonding material to the each of the plurality of lens contact pads or chip contact pads,

wherein the assembly bonding material includes an anisotropic conductive material;

aligning the plurality of lens contact pads with the plurality of chip contact pads;

bonding the chip to the lens substrate via the assembly bonding material using flip chip bonding; and

forming a contact lens with the lens substrate.

16. The method of claim **15**, wherein the creating the plurality of the lens contact pads comprises forming a respective grid of metal lines on the lens substrate, corresponding to the grid of metal lines on the chip, using photolithography.

17. The method of claim **15**, wherein the creating the plurality of the lens contact pads comprises forming a plurality of metal squares, on the lens substrate, having a length of about 100 microns or less.

18. The method of claim **15**, wherein the creating the plurality of the chip contact pads comprises forming the grid of metal lines on the chip using photolithography.

19. The method of claim **15**, wherein the forming the contact lens comprises:

sealing the chip on the lens substrate;

cutting the lens substrate into a ring shape and molding the lens substrate to match a curvature of an eye over which the contact lens is to be worn; and

embedding the lens substrate into a hydrogel.

20. The method of claim **15**, wherein the chip has a thickness of about 100 microns or less and a length of about 1.0 millimeter or less.

21. The method of claim **15**, wherein the anisotropic conductive material has an activation temperature below 200° C.

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